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NOTE.

The authors of the several papers contained in this volume are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

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Erratum.

Proceedings, page xxix, line 7 from bottom, *for* "17th century" *read* "18th century."

Manchester Memoirs, Vol. xlvi. (1901), *No.* 1.

I. The Range of Diotis candidissima, Desf., in England and Wales, and in Ireland.

By Cecil P. Hurst.

(*Communicated by* Charles Bailey, F.L.S.)

Received and read October 1st, 1901.

I have been searching for this plant in England for the last four years, and there can be little doubt that it is a diminishing species, its true home being on the Mediterranean coast. Its occurrence in the Egyptian flora was recorded by my father in Vol. VI., 3rd Series, of the Society's *Memoirs* (1879), page 152, in his "List of Desert Plants collected at Ramleh, near Alexandria, Egypt," &c.

Its comital distribution in *The London Catalogue of British Plants*, ed. 9 (1895), is given as 9, the following being the recorded counties or vice-counties :—Cornwall West, Devon South, Dorset, Isle of Wight, Hants South, Kent East, Essex North, Suffolk East, and Anglesey.

A Cornish botanist (Mr. Fred. H. Davey, of Ponsanooth, near Truro) writes me that it was last seen in Cornwall (vice-county 2) at Praa Sands, a good many years ago. Watson's *New Botanist's Guide* (1835) gives, "near Poole; near Burton, by Bridport," Dorset (county 9), quoting, however, Turner and Dillwyn's *Botanical Guide* (1805), but the Rev. E. F. Linton says he does not think it is a Dorset plant. It had disappeared from the Isle of Wight (vice-county 10) in Dr. Bromfield's time (1856). In Hants South (vice-county 11), Mr. James Groves and Mr. Bolton

King found it very sparingly at Mudeford, near Christchurch, in September, 1879. This station is recorded in Linton's *Flora of Bournemouth*, but Mr. Henry Groves informs me that, on going to the locality a few years later, he could find no trace of it. Marshall and Hanbury's *Flora of Kent*, and Hinde's *Flora of Suffolk*, give it as extinct in the stations recorded for those counties (vice-counties 15 and 25). I have searched unsuccessfully for it in the Isle of Sheppey (East Kent), at Landguard Common, and on the coast between Southwold and Aldborough (all in East Suffolk), including the locality near the buried city of Dunwich, where it used to grow "plentifully" according to Turner and Dillwyn's *Botanical Guide*. North Essex is the remaining English vice-county (19) for which there has been no record of the plant for many years.

The Island of Anglesey (county 52) is the only Welsh county for the plant, and, as far as I can make out, here occurred also the last authentic instance of its being collected in Great Britain. This was in 1896, when Mrs. H. Wynn Sampson, of Carnarvon, according to what Mr. J. E. Griffiths informs me, found three or four plants at Llanddwyn, at the extreme south-west of the island. This place is not far from Abermenai Ferry, where Ray is recorded to have found the plant plentifully. The same lady had previously (in October, 1894) found a single flowerless specimen near Llanfaelog, where, on 5th September, 1727, Brewer saw it "in great plenty for a mile together," but in Davies' time (more than ninety years ago) it was considered to be extinct.

Nearly all the *Diotis* in English herbaria has been derived from the Channel Islands, and here, again, the same record of its disappearance has to be made. In Marquand's *Flora of Guernsey*, published this year, it is

stated that it is extinct in Alderney, where it was found by Babington sixty years ago, at Braye Bay. When Syme was writing the sixth volume of the third edition of *Sowerby's English Botany* (in 1866), he reported it as abundant on the shores of St. Ouen's Bay, Jersey, but Mr. John Piquet, of St. Heliers, tells me that it is extinct there; it used to be found near Kemp's Tower, in St. Ouen's Bay, but the boulders and *débris* thrown up by the sea have exterminated it. The superb patch of *Dianthus gallicus* is not far away from this station, but I could see no trace of *Diotis.*

Turning now to Ireland, I began two years ago to make inquiries as to its occurrence there, and wrote to a dozen Irish botanists for information regarding the plant. They nearly all quoted Mr. H. Chichester Hart's station for it in county Wexford, in 1883, but none of them could tell me whether it still grew there, nor did they seem to have visited the station; no English botanist is known to have been there for a very long time, and on the spot I could only hear of one Irish botanist who had been there once or twice in recent years. In the *Proceedings of the Royal Irish Academy*, 3rd Series, Vol. VII. (1901), p. 174 (also issued separately as *Irish Topographical Botany*), the record for County Kerry is characterised as "dubious." The second edition of the *Cybele Hibernica* (1898), pp. 181, 182, records it as a plant of districts II. (Waterford) and IV. (Wexford). It was first reported as an Irish plant by G. J. Allman, who found it near Dungannon, Waterford, in 1845; and its last record for the same county is "among boulders on the strand at Tramore," by Carroll, in 1854.

Mr. Lloyd Praeger tells me that, to his knowledge, it has not been seen in either of its Waterford stations for half a century. Mr. Phillips, the best Irish southern

botanist, has searched for the plant at Tramore in several recent years, but without success. Mr. John Waddy seems to have been the first to notice it on the bar at Lady's Island Lake, Wexford, and to have communicated his discovery to Syme, who published it in the third edition of *English Botany*. The *Cybele* gives "near Tacumsin Lake" as G. J. Kinahan's station in 1876, and lastly comes Hart, in 1883, with "sandy coast below Lady's Island Lake and Tacumsin Lake, extending for about an English mile." This last-named record induced me to make a special journey to Wexford, and, after a stay there of several weeks, I am able to give the following details of its stations, habitat, &c.

It occurs at the extreme south-eastern end of the county; the most westerly station is on the bar which separates Lake Tacumsin from the sea, just south of Little Ligginstown Island, a tiny islet of Lake Tacumsin marked on the one-inch Ordnance Map; the most easterly station was close to Carnsore Point, near the spot where the granite crops out and renders the coast untenable by the sand-loving *Diotis*. These two stations were separated by about three and a half miles of sandy coast, and, proceeding from west to east, the plant was distributed as follows. For a little over a quarter of a mile at the eastern extremity of the bar which separates Lake Tacumsin from the sea it grew sparingly, and the plants were below the average size. They also appeared to flower earlier and more sparsely than the plants of the Lady's Island Lake, as their flower heads were ripe while the lake plants were still in luxuriant bloom. It grows on the bar at Lake Tacumsin among *Ammophila arundinacea*, and chiefly on the landward side, as is also the case at Lady's Island Lake. I did not meet with any *Diotis* on the small strip of coast which separates the two

lakes. But on the bar which separates Lady's Island Lake from the sea it grows in the greatest profusion for about a mile, save for a tract of about 250 yards where the plant is absent; it is somewhat unevenly distributed on the bar, but it occurs in the greatest luxuriance and abundance at the two extremities, to the exclusion of other vegetation. There are patches of a hundred square yards or more, growing so thickly together as to make their white foliage visible a long way off; many plants are bushy, quite small undershrubs, spreading at the base, and densely covered with flowers. (See *Plates* 1 and 2.)

The bar referred to is about thirty to forty feet in height, with a slope of about 190 paces long on the land side, and one of 64 paces long on the seaward side. Its crest is broken by depressions over which the sea may wash at the highest tides, as drift seaweed was seen fifty or sixty yards on the landward side of the crest. The channels, which are shown on all the recent maps as communicating between the lakes and the sea, no longer exist, broad bars of sand occupying their places; deposition rather than denudation seems, therefore, to be taking place on this portion of the coast, and there is no fear of the plant being destroyed by the inroads of the sea.

In the mile and a half between Lady's Island Lake and Carnsore Point, I saw only twenty plants scattered singly, or in twos and threes at irregular intervals, three of them being close to Carnsore Point itself. At this point its distribution ceased, for although I rounded the Point and walked along the coast northwards for a couple of miles to the little village of Carne, I saw no more of it. I afterwards walked along the east coast from Carne as far northwards as the town of Wexford, but *Diotis* did not reappear.

Although cattle are turned out to browse upon the

coast, the aromatic qualities of *Diotis* render it distasteful to them and thus protect it from injury. The other day I watched some horses reject it with disgust, nor have I seen a single plant exhibiting any signs of having been grazed upon. It is, therefore, not likely to be exterminated by man or beast. Inroads of the sea may have had something to do with its disappearance in some of the English localities. One botanist suggests that inability to ripen its seeds properly may have something to do with its gradual extinction, especially as it has so little competition with other plants when growing on the sea-shore. The plants in the Irish locality seem to be maturing their seeds, and I saw undoubted seedlings. It is curious that the plant should be nearly extinct in Great Britain, where it has been known to grow for over two hundred years; while in Ireland, for which the first record is less than sixty years old, it should still grow plentifully.

Amongst other plants which I have found in this neighbourhood were *Lemna polyrhiza, Salix Hoffmanniana, Atriplex laciniata*, all first records for District IV. The occurrence of the last-named plant is a great southward extension of the species; it grows close to Kelly's hotel, at Rosslare, which I made my headquarters, and it extends along the coast for about half a mile to the south. Other interesting species noted were *Polygonum maculatum, Rumex maritimus, Cuscuta Trifolii, Lemna gibba, Buda rupestris, Juncus acutus, Viola Curtisii, Zostera nana, Potentilla procumbens*, &c.

I send specimens collected at Lady's Island Lake, 11th September, 1901, as well as examples from Mr. Charles Bailey's herbarium, collected as follows:—

Near Bideford, North Devon (vice-county 4), collected by R. Hawker, without date of collection, this vice-county not being included in *Topographical Botany*, ed. ii., p. 250;

St. Ouen's Bay, Jersey, collected September, 1842, by Mr. G. H. K. Thwaites;

—— collected 1847, by Mr. G. H. K. Thwaites;

—— collected August, 1851, by Mr. W. Stevens;

—— collected 17th August, 1867, by Mr. Charles Bailey, when he found it scarce;

—— collected August, 1879, by Mr. John Comber;

—— collected 15th July, 1882, by Mr. A. E. Lomax;

From the sea-shore near Christchurch, South Hants, by Mr. Bolton King, September, 1879; and Mr. James Groves, same locality, 15th September, 1879.

PLATES I. AND II.

Both photographs were taken at the western extremity of the bar at Lady's Island Lake, on October 15th, 1901.

Plate 1. Looking southward across the bar. There are a few plants of *Euphorbia Paralias* in the foreground, recognisable by their dark colour in the photograph. The sandy, gravel-strewn nature of the soil affected by *Diotis* is better shown in *Plate* 2. The young plants of *Diotis* approximate so much in colour to the grey pebbles among which they grow, as sometimes to be with difficulty distinguished from them.

Plate 2. Looking westward along the bar. The plants in the foreground are rather more weather-beaten than those in *Plate* 1. The way in which *Diotis* monopolises the ground in this locality, stretching far away into the distance, is well shown in this photograph. The shrubby nature of the more luxuriant plants is also noticeable.

Photo by W. Andrews and Son, Wexford and Enniscorthy.

DIOTIS CANDIDISSIMA

Photo by W. [illegible] and Son, Wexford and Enniscorthy.

DIOTIS CANDIDISSIMA

Manchester Memoirs, Vol. xlvi. (1901), *No.* 2.

II. On the "Implements from the Chalk Plateau," in Kent, their Character and Importance.

By R. D. Darbishire, F.S.A.

Received and read October 15th, 1901.

I have ventured to intrude upon your attention chiefly on account of the special human interest of a subject to which I have myself devoted very sympathetic consideration, and which I desire to help to vindicate against a good deal of what seems to be mostly half knowledge and prejudice.

I myself cannot profess to be scientifically familiar with the geological position of the ground I am going to take you upon, nor indeed can I claim any distinctive position, beyond that of a student and a collector for very many years past, as to the objects to which I shall call your attention.

The country is what is called the Weald of Kent, and the chalk Plateau through which it has been cut, and, above all, certain deposits overlying this Plateau.

At some period of remote antiquity, of which we have no possible measure, the chalk was formed at the bottom of the ocean, and afterwards a considerable mass of tertiary deposits of various kinds was cast down over it. Next, the whole of this portion of the earth's surface appears to have been raised—some geologists say 6,000 feet—, at any rate, far above the sea-level, with the tertiary beds at the top.

It is difficult to define the successive alterations of the surface of the earth which have left it such as we now see.

December 9th, 1901.

Apparently the elevated chalk and its covering beds were subjected to enormous denudation, and, within the space between the present chalk escarpments, north and south, a vast excavation took place forming the great valley of the Kentish Weald.

The agency of such changes may be supposed to have been the wasting degradation and removal, and at last a certain redisposition, by means of river-flow, possibly in former times vastly greater than at present. Those antecedent rivers, now represented by the Thames, the Medway, the Darent, and others, swept down, age after age, more and more *débris*, each succeeding deposit presenting outwash from preceding ones, mixed up with its own peculiar mass.

The occurrence upon the denuded chalk of a great bed of drift material, mostly of a reddish clay with some sandy infusion, bespeaks in itself in part the agency of mighty preceding movements of water wearing down the raised strata and leaving its characteristic "river-gravel," though now we cannot trace the beds of such streams.

As is usual, these recent strata are characterised by their fossils, partly of animals no longer existing here or elsewhere, or of others still represented amongst us. So far, I believe, no remains of animals have occurred in this earliest drift.

The strata are also often distinguishable by the general characters of separate beds. But with regard to nearly all these river-gravels, there is a remarkable line of very peculiar fossils, showing distinctly the handiwork of man, commonly called stone implements. These constitute the only remains that Man's earliest intellect and skill have prepared and left to us.

All are primarily marked, as having been shaped by what is called "chipping," and exhibit varying designs

and forms. Their forms are fairly permanent, and, in general terms, often appear to distinguish the successive beds, and, no doubt, the succeeding races of makers.

It is with these stone implements that we are concerned at present. They are in truth the fossil records of the thought and development of successive races of men, and are thus of singular interest to us all. They are found often in considerable abundance amongst the drift or gravels of the district. These river-gravel implements exhibit definite marks of successive advance in conception, execution, and, no doubt, application. In connection with similar observations in other countries, they have been rudely classified as "palæolithic," *i.e.*, stones of the older sort, and "neolithic," those of a newer order. The latter exhibit a certain improvement as to workmanship, form and application, advancing from rude flaking or chipping in the nameless forms of older times to the highly-finished and polished axes, chisels, spear-heads, and arrow-points of races of the age immediately preceding our own, or perhaps, even extending within historical limits.

It will be in the recollection of many of us that a little more than 40 years ago Sir John Evans and the late Sir Joseph Prestwich announced to the English public, and not only so, but vindicated to the scientific world of the day, the fact that an enthusiastic French Geologist had really discovered, amongst the gravel beds near the mouth of the River Somme at Abbeville, stones manifestly worked by the hand of man, in immediate conjunction with the remains of rhinoceroses, elephants and other extinct animals.

It was in 1847 that M. Boucher de Perthes published his book on "Antiquités celtiques et antédiluviennes," in which he stated and showed, with many illustrations

from his own long-continued and very great collections, the fact of his discovery. Unfortunately, M. de Perthes mixed up with his identification of manufactured tools many conjectures as to the nature and use of other stones which had occurred to his hand, and in which he imagined he could trace figures or idols or other objects of undoubtedly purely fanciful conception.

The whole idea was so extraordinarily novel to even cultivated geologists of that day, and was so confused with other matter of the kind referred to, that his discoveries were ridiculed and scouted in France and elsewhere, and for many years the discoverer had no defender except Dr. Rigollot of Amiens, who, having first scoffed, prosecuted his researches in alliance with his friend, and eventually became his most pertinacious ally.

Still, partly from want of sufficient free intercourse between the scientific men of the two countries, whatever intelligence of these alleged discoveries had passed into England was entirely disregarded until, in November 1858, Dr. Hugh Falconer (already amply trained in observation of recent deposits, and especially in the study of the latest races of animals before those of the present epoch), while travelling from England to the South, introduced himself to M. de Perthes and examined his collections, and was satisfied of their proof of an indubitable co-existence of man and the animals of the superficial deposits of the so-called quaternary sands and gravels.

Convinced of the reality of the discovery, he reported it in a letter to Mr. Prestwich, who had already acquired the reputation of being one of the ablest of geological observers of his time, and especially unrivalled in his knowledge of these latest sands and gravels. As an immediate consequence of this communication, in April, 1859, Mr. Prestwich visited Abbeville, and inspected the

collections and strata themselves. He was immediately joined by Mr. Evans, then also well-known for his geological knowledge, and for his special familiarity with what are generally classified as stone implements. These gentlemen personally investigated not only the collections but the beds themselves, and extracted implements from the unbroken strata.

In 1860, Mr. Evans read before the Society of Antiquaries his great paper "On the occurence of Flint Implements in undisturbed Beds of Gravel, Sand, and Clay." He was familiar with flint implements of great age found in river-gravels in England, namely, in particular, one in an excavation in Gray's Inn Lane, London, so long ago as 1715 (which is now in the British Museum), and others at Hoxne, and similar instruments found in gravels by himself at Reculvers and from gravels in the valley of the Ouse, near Bedford. All these were by this time well known and reckoned as obviously of human manufacture. These particular series consist almost exclusively of flatly conical pieces of hard stone with a round head, sometimes of unbroken surface, sometimes chipped, and a long, pointed end carefully shaped by chipping on either side or on both sides and at the points, commonly called axes.

To these were added, as discoveries proceeded, a flatter, somewhat cake-shaped form, carefully chipped on both sides and on all edges, mostly rudely oval in shape.

All these generally exhibit, when made of flint, a surface peculiarly glazed, sometimes even patinated, that is to say, exhibiting a certain mineralogical modification of the external surface, and many show signs, moreover, of having been more or less washed about amongst pebbles or sand, in a certain softening of the edges of the chipped portions, and their peculiarly glazed natural polish.

Mr. Evans' announcement stimulated a host of searchers and discoverers, and reports of various findings were received from various parts of the country.

In mineralogical character these implements vary from flint, the characteristic hard material of the chalk district, to various forms of chert elsewhere. All are characterised by definite special forms of manufacture and shape, and generally are easily discriminated from similar pieces of natural fracture.

One of the most remarkable sources of implements of the latter group, was the valley of the Axe in Dorsetshire. From large quarries known as Broom Pits, near Axminster, the skilled science of the curators of the celebrated Blackmore Museum at Salisbury soon stored a most wonderful collection. Large gravel pits at Swanscombe, on the Thames, and at Aylesford, on the Medway, also supplied many beautiful specimens, but of more recent forms.

For the purposes of my present paper I have placed on the table examples of the French and of several English series of these implements.

When the British Association met in Manchester, in 1861, Mr. Evans, with whom I had had some previous communication on similar subjects, was kind enough to send me for exhibition here a series of the then recently discovered and published "Implements from the Valley of the Somme."

The whole of these discoveries opened so new a page in scientific history of the surface of the world and its inhabitants, that they immediately raised questions of the most embarrassing kind, not only as to the actual chronological interval between their deposit in the gravels and their discovery to-day, but as to the inevitable implication of the question of the existence in remote antiquity and the duration in this part of the world of men able to make and use these implements.

Many conjectural calculations have been offered as to the time and deposit of these valley gravels, but, so far as I know, there is not any correlation of geological and historical time relating to them.

They prove the existence of man at the time of deposit of the quaternary gravels, and that is all.

Certain comparisons between the implements till lately used by the North American Indians and by the Australians are here and there giving hints as to the use of some such implements.

Many discoveries of implements not very different in form, made by Mr. Seton Karr in Somaliland and in the Egyptian Eastern Desert, seem to indicate that some use of similar implements may have continued even later on in the recent geological period, apparently mixing up "palæolithic" forms with some of "neolithic" shape. With all the thousands of such implements, passed from hand to hand by keen observers, it has as yet been impossible to say what was the precise use to which they were applied or how they were distributed in their strata.

It is not very surprising that even the imagination of men of the highest scientific culture of this day should be unable to throw back their interpretation, so as to explain how the man of the Valley of the Somme, of the Ouse, or of the Axe, made his tools, much less how he used them.

We say the Man, because complete familiarity with the forms and with the resulting comparisons of his manufacture, indicates distinctly not only handiwork, but specifically intellectual human design in the adaptation of his implements to some particular use.

When we recollect that 6,000 years ago the Egyptian workman carried his tools in a bass bag, just as every joiner does to this day, we need not wonder that the form of the pointed axe-head and the ovoid implement lasted through periods of which we have no date or measure.

They prove, at all events, that man existed ages before any possible historical record, and pursued his life, whatever it was, under conditions and with purposes which we, in truth, cannot at all reproduce or conceive of.

The interest and importance attached to these particular discoveries have fascinated students of all classes, from scientific observers of the highest reputation to the hundreds of collectors, and to the thousands of wondering observers in our greater Museums.

I have no pretension to speak for the geologists. What little familiarity I have with such questions is almost entirely that of the desk only, but this discovery literally inflamed my mind, and for the last 40 years, whenever I have had the opportunity in public museums or private associations and in various localities, I have examined and handled specimens of this particular class, and I am certainly not without a very real familiarity with the signs of what we may distinguish once for all as *manufacture*, and otherwise of palpable distinction from natural fractures due to frost or to movement and chafing in water courses or in the shifting drifts which now reveal them to our eyes.

From various parts of Europe, from various parts of Africa and from India, many series of these pre-historic implements have been brought within skilled survey, and all that they really tell us is to repeat the lesson of a particular design for particular use, and of a certain observable gradual increase in the perfection of manufacture; as if similar needs stimulated similar inventions and practice amongst the earliest tribes, which we distinguish as those of Man, all the world over.

All these particulars are, however, now matters of common knowledge, but in 1891-2 Mr. Prestwich published in the *Journal of the Anthropological Institute* a paper by

himself, with notes by Mr. Benjamin Harrison and Mr. Crawshay, on "The Primitive Character of the Flint Implements of the Chalk Plateau of Kent"

Without going into further detail, I may explain that, from the River Medway westward to the River Darent and further westward still, there is a long mass of chalk broken southwards with an escarpment. On the very top of large portions of this chalk there are the remains of the bed of a red clay drift above referred to. It was described by Mr. Prestwich as from 5 to 20 feet thick. In process of time great water channels have been cut through this to expose the chalk.

This red gravel bed stands high above the level of the sea. Mr. Prestwich in his paper enumerates 22 distinct localities levelled at 400 feet, at West Yoke Farm 460 feet, at South Ash 520 feet, at Plaxdale 630 feet, at Terry's Ledge 770 feet, all therefore antecedent to the mighty denudation of the Weald; and long preceding the later river valley drifts and deposits of lower levels. It is from one or other of these particular stations that the specimens presented for examination have been taken.

In 1869, Mr. Prestwich and Mr. Evans found on a certain farm near Halstead, on the chalk Plateau, a palæolithic instrument of the ovoid shape, at a point 600 feet above the sea level.

In 1883, a similar implement was found on the Darent, by Mr. Benjamin Harrison, of Ightham, near Sevenoaks, on the chalk at the same level of 600 feet.

Gradually,—greatly excited by the discovery—Mr. Harrison, a most indefatigable and most accurate observer, instituted his own search, frequently submitting specimens which he discovered to Mr. Prestwich for examination and certificate, and several other geologists of note prosecuted similar research with great success.

This characteristic development has realised in Mr. Harrison's own collection more than 5,000 of what are known as plateau implements. Mr. Crawshay, the Rev. R. A. Bullen, Mr. Bell, Mr. W. J. L. Abbott and many others have made large collections of the kind, and many valuable communications have been made to various scientific societies from one or other observers, and the whole subject has also been sympathetically reviewed by men of such extended scientific familiarity and philosophical accuracy as Mr. Grant Allen and Mr. Andrew Lang, whom we may well call in this case unprofessional witnesses. Each of these has written on the remains in question with genial acceptance.

There are still, of course, sceptics some of whom question the claim of these plateau implements to be even manufactured at all,—a most absurd doubt indeed!

Plateau specimens are almost uniformly of a dark flint, very heavily patinated with a reddish orange surface, in itself a proof of enormous antiquity of exposure to the patinating influences, whatever they were.

These specimens appear to have been pieces of natural flint, more or less artifically chipped, as I shall show, into particular shapes.

Of course, anyone who has attempted this research at all is familiar with the effects produced by natural causes, such as characteristic mineralogical formation, the intrusion of water and the expansion of frost, or the accidental collision of stones in the watercourse, or, in not a few cases, the accidental formation of frost splints of rock and their separation from the matrix; and at the same time, with the large occurrence of chips or imperfect tools thrown away by the workers.

The common charge against the plateau implements is that they are the work of these natural causes and not

of human hands, or at best what the doubter stigmatises as "wastrels."

No one doubts the occurrence of natural forms with or without modification, but, as I hope to satisfy you, it is neither scientific nor even just to condemn the research on account of such occurrences.

Sir John Evans complains, in reference to the plateau implements, "that it is truly an irony of fate "that one, who has for forty years defended the "artificial origin of Palæolithic axes, finds himself at this "day obliged to object to the facility with which people "sometimes consider simply flaked flints as indisputably "the result of human labour." This reflection is certainly limited in its range, but it is widely used to confirm scepticism.

In a paper read before the Geological Society in 1898, Mr. W. Cunnington, after examining in detail certain specimens, pronounced that they were clearly either of the age of the river-gravel specimens which we have considered before, or had been chipped by natural agencies, such as movement in beds of frozen or thawing gravel, and, if not, the marginal chipping must be held to be the work of man after the palæolithic race.

The discussion in the Society was summed up by the President's declaration that the author's argument had conclusively disproved the claim that the Kent Plateau had been the home of the primitive palæolithic people.

One cannot help wondering whether the survey of the author or the judge had not, in fact, been of a range of specimens of only the narrowest and even, perhaps, confused selection.

It is understood that our own geologist, Professor Boyd Dawkins, shares the scepticisms and objections of Sir John Evans; and Sir Henry Howorth has recently

confessed himself one of the sceptical critics, and complains that he "had seen very few implements which seemed to "him to have any purpose or motive of any kind."

It is convenient to recollect the distinction between pre-historic implements that have been classed as "neolithic"—as exhibiting a more recent and advanced culture in form and workmanship—and "palæolithic," as referring to stones simply chipped into shape.

The usual localities for the finding of these classes of implements are the surface of burial places or in morasses for the neolithic tools, and, as noted above, the river valleys, older or more recent, for the palæolithic remains, or, in either case, even the present face of the ground.

As a further step in identification of their position and elevation, and from the comparatively restricted material and condition of the plateau stones, it is customary to group them as "eolithic," that is to say, stones of the time of the dawn of such manufacture and use.

If the palæolithic discoveries indefinitely enlarged the pre-historic existence of mankind, it has been thought and believed by many skilled observers of long research and large survey that these plateau gravels and their contents carry the story for ages further back.

Palæolithic man is now a recognised ancestor of the race, and he has certainly left tools of absolutely unmistakable design and skill, though we may not know how he used them. We have no other proof of his existence.

It is indeed startling to find on this plateau, at such levels above the sea as bespeak an age indefinitely greater than that of the ordinary river-gravel series, vast numbers of stones of uniform and very peculiar design and of uniform skill in shape, which it is impossible not to consider distinctly evidential of intellect and skill

which, so far, we have no other mode of naming than as those of Man.

It is in the special interest of this view that I venture, after so long a preface, to call attention to a series which I have been allowed by Mr. Harrison to select from his stores, and have arranged with very great care for the special purpose of exhibiting full and characteristic series of representations such as, I maintain, are unquestionable proofs of design and skill in these most ancient stones.

It does not in the least matter that no one now living on the face of the earth is likely to be able to understand what was the design of him whom we will call Eolithic man, or his mode of life, or his manner of using his implements. It is enough for us to show that these implements exhibit definite lines of invention, so many several "patents," as one might call them, deliberately and successfully worked out.

In such an investigation as the present, it is necessary to bear in mind the primary condition of proof in the rational establishment of facts. One stone may be found with a remarkable signation which may well be compared with the broken stones of the stream or of surface frost. But search, and find another, and another, and many hundreds of repetitions of precisely the same fracture, and it is impossible not to see design and practice, *i.e.*, manufacture, and that by the only animal that uses his head and his hands for the purpose.

Without having had the opportunity of personal repeated recourse to the plateau gravels, I can at least say that under Mr. Harrison's guidance I have examined several of his localities, and at one of them, namely at Terry's Ledge, 700 feet above the level of the sea, in the course of a couple of hours I was myself enabled to find, in a deep trench, a handful of these eolithic tools.

For my present purpose then I will call your special attention in the first place to a case which I have marked No. 1. In this tray there are 16 of the ruddy flints varying in size from the half of a pebble, an inch and a quarter in diameter, to a piece of flint 5 inches long, every one of which exhibits a very distinct curve on one side or on both sides, most like what remains after a piece has been bitten out from a cake.

These curves are uniformly marked by systematic chipping away of the former edge of the lump of flint, in a new and—piece after piece—identical form. It is not difficult to lay one of these curved edges upon another and to see the very same curve represented in each specimen, precisely as clearly as is seen under the celebrated Whitworth gauges. That curve was most certainly a "patent" of that day.

In the same tray there are three specimens in which on one edge the curve is duplicated, so as to make two curves, separated by a nipple, as it were, between them, a form equally certainly, deliberately completed.

Some of these stones are marked by absolutely distinct chips, which may be water wear or the marks of frost chips.

In the second tray I have arranged 19 specimens, varying from one inch to about four inches in diameter, every one of which has been shaped by special chipping, so as to exhibit a medial terminal point between two concurrent curves, equally manifestly another "patent."

In a third case I have brought together a number of obviously natural stones, either designedly or accidentally split off from a larger piece, but every one of them marked with the characteristic lateral chipping. This chipping is not like the beautiful systematic work of the palæolithic axe or the neolithic scraper, but is always so arranged as

to break off the edge of the stone and to make it more characteristically serviceable for some particular use, this "breaking" being a small flaking *perpendicularly* through the thickness of the stone, and not flaking to an edge.

By way of indication that my construction of my specimens is not fanciful, I have in another case accumulated together 50 picked specimens of the smallest of these tools, with the curve and the point, and the lateral vertical chipping manifestly exhibited.

After looking at all these and at hundreds more, I observe, confidently, that I have never seen in any one palæolithic implement anything at all like the systematic form of the working of the eoliths. I venture to add further that I, at least, have never seen of palæolithic make any of the smaller sorts.

I have no right to plead my familiarity with the subject, such as it is, as sufficient for positive judgment: but I do contend that it is impossible to pass by these series without being satisfied as to the artifical intention and particular character and purposefulness of every one of these implements, and of their peculiar and special preparation.

By way of further illustration, I have added a tray of these implements from South Ash, another from West Yoke, and one from Terry's Ledge at 700 feet, from which, I think, any practised observer would be able at once to recognise what the naturalists call the *facies* of the deposit, and to distinguish it finally from the later and improved palæolithic specimens.

In one other case I exhibit two or three specimens, so peculiar that I had serious doubts whether they were not what the sceptics call natural stones. One is a large tool, 8 inches long, combining the lateral curve with a chipped end. Another one might call a sort of hammer stone. It

exhibits the lateral curve and at one place a succession of flaking marks of a very marked and characteristic beauty. This stone has apparently been selected for having a prominence on the back, which enables a man to have a much firmer grip of it. One might have called this accidental, and a chance single stone, but for the fact that I have got another pointed specimen with the lateral point, the vertical chipped edges, and the handle prominence. I show also another grand specimen, measuring 10 inches by 8 inches, and weighing 5½lbs., also exhibiting the lateral curves, the vertical chipping, and a prominent handle. The series is complete, from these great tools down to some as small as a sixpence and weighing less than half an ounce.

One day while I was exploiting the collections in the British Museum for illustration of my subject, I was delighted to find a specimen from near Bland, Dorsetshire, of a shape almost exactly corresponding with one of these great plateau stones.

Before I conclude, let me repeat again that I personally cannot claim for myself or my statements any other authority than that of a faithful private study of stone implements from many parts of the old and new worlds, and the continuous handling of such specimens in various museums here and abroad, and in my own collections.

There is very much in this great province which I do not know and cannot speak about, but I have a certain, and, to my mind, a fairly reliable experience of, firstly, the distinction between stones of natural fracture and those which exhibit designed manufacture, and, secondly, of the distinctions between earlier and later implements.

Upon this basis I am convinced, in the first place, that the eolithic series is certainly manufactured, and, further, that it is of a conception and execution entirely distinct

from any palæolithic or later implements, and distinctly a less perfect, less variable, and so much the earlier production of the hand of man.

I submit that, so far as my long series of specimens, and much more the collections of Mr. Harrison and others, show, and as any judgment of my own extends, the Plateau Implements are rightly so called, and, as such, manifest appropriate and absolute peculiarities of material, of form, and of special adaptation, of manufacturing design, skill and habit, and of remotest age,—so far as we have yet been able to observe.

And, finally, I declare my own unhesitating concurrence with those perhaps less limited, less embarrassed, but more skilful, and more learned observers who believe that, in his discovery and publication of his eolithic remains, Mr. Harrison has unveiled the fossil indications of the mind, purpose, and character of a race of men of an age long preceding that of the palæolithic man, and has established an antecedent geological era for the habitation in this country of the human race.

It is truly remarkable to think of Man even then endowed with intellect, invention, skill, purposes and perseverance ; the very same powers and principles which still fundamentally characterise the race—that same race which, since blessed with the great developments and inheritances of literature and religion, has grown to be what it now is ; and that man has so far steadily framed his course onwards towards what he is and shall yet be in fuller consciousness of Him who hath made us all from the beginning.

EPITOME OF PROOFS.

(1) The peculiar character (*a*) of the material used, and (*b*) of the uniform and extreme 'patination' of most specimens.

(2) The peculiar shapes of the same, showing several separate designs

(*c*) in lateral curves (like bites out of a cake), sometimes duplicated with a point left between.

(*d*) in instruments with bold lateral curves on each side of a strong, sometimes sharp, sometimes obtuse point.

(*e*) in flat flints, with chipped edges more or less all round, and

(*f*) in repudiation of a rambling dismissal of the remains in question as "wastrels."

(3) The peculiar and original fashion of chipping the flint *perpendicularly through the thickness* so as to remove the natural edge (sharp and rough) of the stone, and the general absence of work on the sides of the tool.

(4) The collective facies of the mass, unembarrassed by admixture of forms known as palæolithic.

(5) The accumulation of tools of each particular form (or "patent") *of all sizes*, from ½-inch to 10″ by 8″, and weighing from ½oz. to 5½lbs.

EXPLANATION OF PLATES.

Plate 3. Diagram showing denudation of the Weald and chalk escarpments and Plateau drift.

Plates 4 to 8. Photographs shewing characteristic forms of implements.

N

T. Tertiary Strata.

1. Chalk.

2. Upper Greensand and Gault.

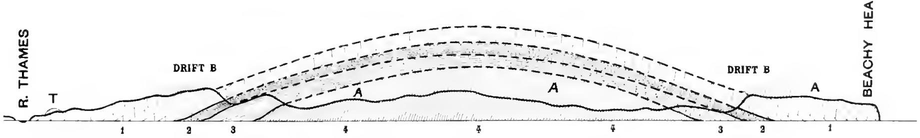
3. Lower Greensand.

A. The present Land Surface shewing the Chalk Escarpments at B and B.

The Valley between B and B is that of the Weald of Kent.

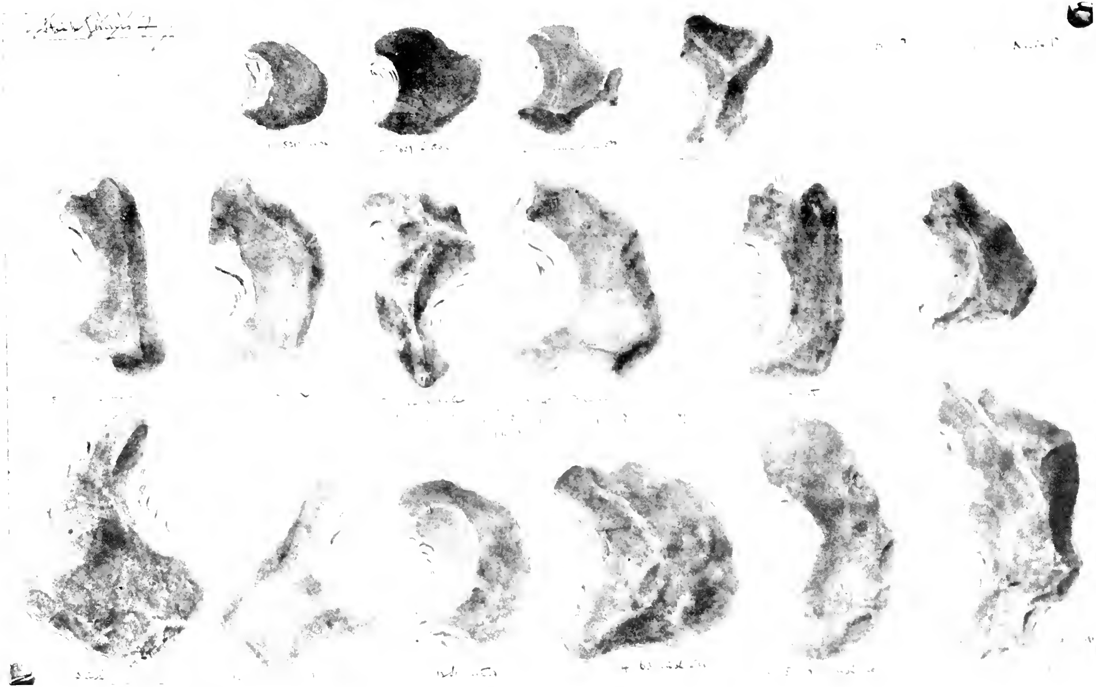
The Plateau Drift is marked ____

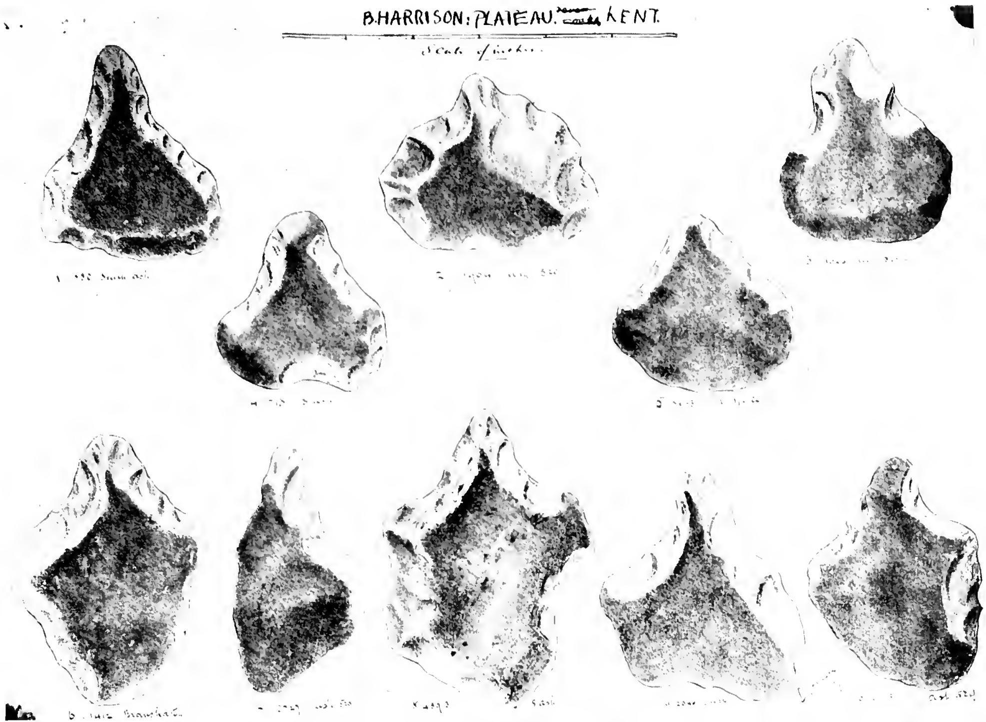
DIAGRAM
SHEWING
THE ANCIENT WEALDEN HEIGHTS
AND
PRESENT VALLEY
(AND DENUDATION.)



SCALE :—1 INCH TO 500 FEET VERTICAL.

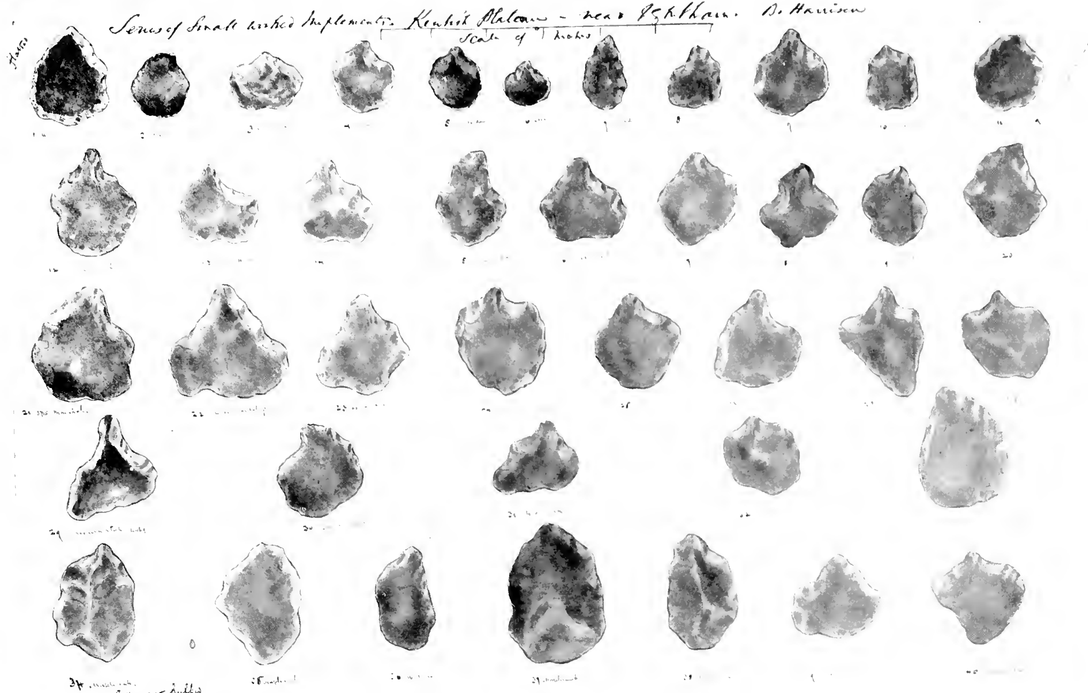
Plate 4.




B.HARRISON: PLATEAU. KENT.
Scale of inches

Manchester Memoirs, Vol. XLVI.

Plate 6.

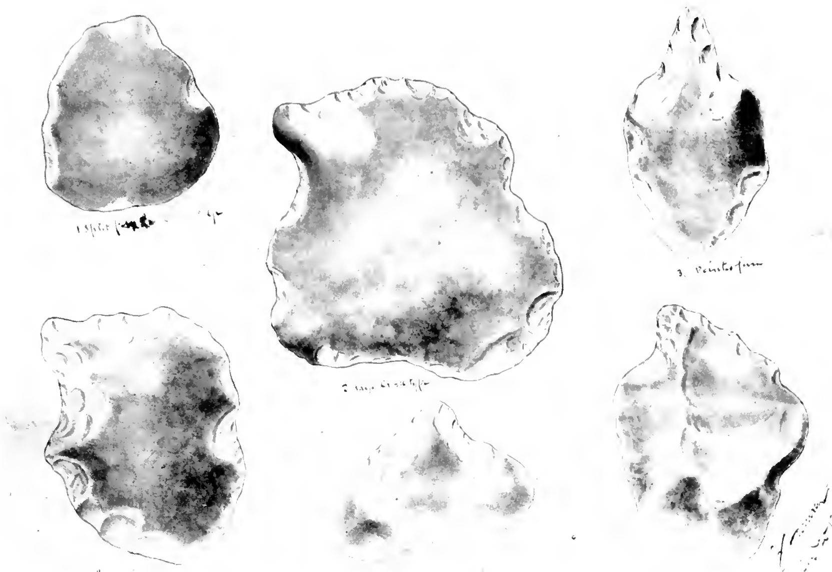


From Pts dwg for British Association 1894

No. 3. Exhibited at Royal Society's Soiree 1895

PLATEAU: KENT.

Scale of inches



Kentish Plateau – Darent Valley. B. Harrison
Ightham.

Scale of inches

1. Pit 1890 [illegible]

2. 1894 Pit [illegible] 5" 3" [illegible]

3. Pit 1894 [illegible]

Manchester Memoirs, Vol. xlvi. (1901), *No.* 3.

III. On Explosions of Steam Pipes due to Water-Hammers.

By C. E. Stromeyer, M.Inst.C.E.

Received and read October 29th, 1901.

Since the Board of Trade Commissioners began to inquire into explosions of steam vessels seventeen years have elapsed, and fifty cases of steam-pipe explosions due to water-hammer action have been reported upon by them. In nearly all these cases the explosions were brought about as follows :—

The steam pipes connecting a set of boilers generally consisted of a horizontal length ending in a vertical bend. (See *Fig.* 1.) One boiler would be out of use, and its

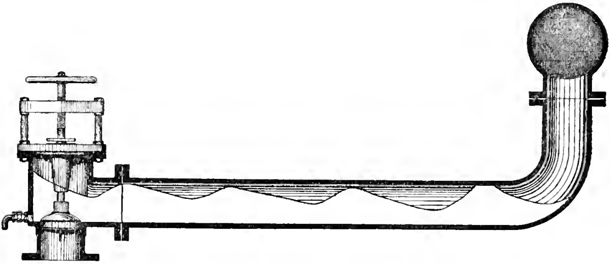
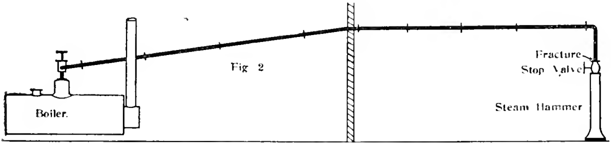


Fig. 1.

bent steam pipe would be full of condensed water, the lower part of which would be cold, while the top surface in the vertical bend would be in contact with high-pressure steam of the other boilers and would be hot. Steam

would now be raised in the disused boiler, and, before opening its valve, the attendant would open the drain cock of the pipe to let out the condensed water. Then, as soon as the water-level had sunk below the top of the horizontal pipe, the steam in the vertical pipe would rush into the small channel thus formed, and, having access to the portion of cold water near the valve, condensation would produce a powerful inrush of steam, which would sweep up waves of water as shewn in *Fig.* 1. According to most accounts of such accidents, this commotion is so intense as to shake the steam pipes violently, and in a few seconds they or their valves are shattered. We have here three very complicated problems to consider, the rate of condensation of steam, the wave-making power of the in-rushing steam, and the intensity of the resultant water-hammer. It is only with the last of these problems that I can deal in the present paper, though it is represented by only a small number of steam pipe explosions.



Imagine a single boiler connected to a pipe, as in *Fig.* 2, leading to an engine (in this case a steam hammer); imagine water to be collected in the steam pipe near the boiler, and that the engine valve is partially open; then, on opening the boiler stop-valve, the plug of water in the pipe near the boiler will be shot along the pipe to the engine, and either smash the valve or close it and smash the pipe or valve chest. This action would also take place if all the valves and pipe joints were so tight that a vacuum existed above the water pocket. Then, again,

on opening the boiler stop-valve, the plug of water would be shot along the pipe to the engine, and would shatter the end of the pipe.

To understand the action of a water-hammer, we have to study the question of an elastic blow ; this has been been done by many mathematicians, notably M. de Saint-Venant, whose view that the velocities of sound-waves and pressure-waves are the same have been generally accepted, but he does not help one over the difficulty pointed out by Dr. A. Ritter[1] that waves are undulatory, while a pressure-wave implies at least the possibility of absolute discontinuity of motion, *i.e.*, that a particle of matter may have its velocity changed with absolute suddenness by a definite pressure According to Saint-Venant[2], the pressure in a bar travels at a uniform velocity ; and, as far as the pressure extends, the bar will shorten ; hence he finds a velocity for the propagation of the pressure which agrees with the velocity of sound, but he does not deal with the shape of the front (as it were) of the pressure-wave, nor does he say whether the pressure grows suddenly or only fairly suddenly, and it might well be that a gradual pressure might travel as fast as sound, while a very sudden pressure might have another velocity. In 1871, Dr. John Hopkinson read two papers before the Society on the conditions under which wires can be ruptured by a falling weight, while Dr. A. Ritter's paper deals with adiabatic expansion ; in both papers the leading idea is the same, *viz.*, that the pressure can be estimated by a comparison of the velocity of the object as a whole with the velocity of the pressure-wave in the object.

Dr. Hopkinson considers that pressure-waves travel with the velocity of sound in the wire, while Dr. Ritter

[1] *Wiedemann's Annalen*, Bd. 37 (1889), p. 634.

[2] *Comptes Rendus*, Tome 64 (1867), p. 1192.

suggests that these two velocities may be the same, but gives no very precise proof. Dr. Hopkinson seems to have overlooked the point on which Dr. Ritter insists, *viz.*, that the pressure of a pressure-wave in a prismatic bar is independent of the length of the bar. Dr. Hopkinson's formula is

$$\text{Tension} = \frac{V.E}{\mu . a}\left(1 - \epsilon^{\frac{-\mu(at-x)}{M}}\right).$$

He made some very valuable experiments which prove one of the points on which both investigators insist, *viz.*, that the greatest stress is first experienced not at the moving end, *i.e.*, near the falling weight or moving piston, but at the fixed end. These experiments will be dealt with later.

The problem of water-hammer will be considered on the lines followed by Dr. Ritter. It is a very common experience at country stations to see a goods train either being brought to rest or being set in motion by the engine. In the latter case the trucks are in contact and the couplings slack, the engine starts, moving with a velocity V, which, for a few seconds at least, may be considered constant. The engine at first pulls only the first truck, which acquires the velocity V; engine and truck No. 1 move together at this velocity till the second chain, an elastic body, is pulled tight, and, on the principle of the elastic blow, the second truck at once attains the velocity V; truck No 1 would at once come to rest were it not being moved on steadily by the locomotive. Then, with a succession of bangs (elastic blows), the remaining trucks, one after another, acquire the velocity V until the whole train moves with this velocity. Now, it will be noticed that the wave of percussion travels along the train at a much greater velocity (W) than the locomotive or the trucks are moving. The reverse phenomenon always

happens when the locomotive decreases its speed with moderate suddenness, and naturally also when coming to rest; but in these cases, of course, it is the buffers and not the couplings which have to bear the blows. Under favourable conditions one may occasionally notice a reflection of the pressure-pull wave from the last truck, particularly if it be an empty one, because the pull between the two last trucks is in excess of the wheel friction, and imparts to this truck a velocity $2V$; this is imparted to the next truck, and so on, and we thus hear first a wave of successive blows travelling along the train from the engine to the last truck, and then travelling back again.

Suppose that the chains and buffers are elastic, as with passenger cars, and suppose also that there is no wheel friction, while the energy expended by the locomotive is just sufficient to keep it moving steadily at the velocity V, in spite of the ever-increasing load; then, when the wave returning from the last car reaches the front end, the whole train will be moving with a velocity $2V$. The locomotive is still expending energy and will now at once acquire the velocity $3V$; a new wave transmitting this velocity will travel to the tail end, and on its return will impart a still higher velocity to the locomotive. Thus a steady pull of a locomotive accelerates the train in jerks. Similarly, with a gas explosion in a pipe, although the combustion may be steady, the pressure ought to rise in jerks. This conclusion, leading to a questioning of the second law of thermodynamics, seems to have been Dr. Ritter's chief objective, but he also deals with Dr. Hopkinson's theory, that the pull on a wire is twice as great at the fixed end as at the loose one. If Dr. Ritter's views are correct, and there can be little doubt about them, the explosion of a gas in a tube should be a musical note of rapidly increasing pitch, which, under favourable conditions, might be recorded in a phonograph.

The problem of the elastic blow can be illustrated as in *Figs.* 3 to 6.

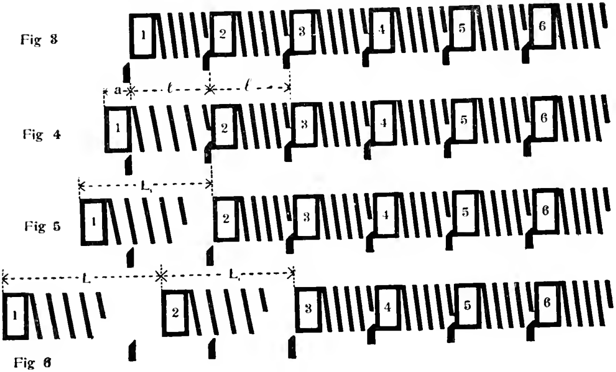


Fig 3, Fig 4, Fig 5, Fig 6

In *Fig.* 3 we have a number of small blocks 1, 2, 3, each one of the mass m, and to each is attached a weightless spring, the length of the block and spring combined being $(l+a)$ when in an uncompressed condition, while when compressed to the length l the pressure exerted by the spring is P. These blocks rest on a perfectly frictionless surface, from which catches project at distances l; these catches are to be successively withdrawn, the interval of time between each withdrawal being t. In *Fig.* 3, the first catch has just been withdrawn, but the block has not yet moved. In *Fig.* 4 the spring of block 1 has extended to its full length $(l+a)$, the time required to do this being $\frac{\pi}{2}\sqrt{\frac{a\,.\,m}{P}}$, while the velocity imparted to the block and spring in this time is $V = \sqrt{\frac{P\,.\,a}{m}}$. After a lapse of time t, the first block will have travelled to a distance

$$L_1 = l + a + V\left(t - \frac{\pi}{2}\sqrt{\frac{a\,.\,m}{P}}\right) = t\sqrt{\frac{P\,.\,a}{m}} + l - a\left(\frac{\pi}{2} - 1\right).$$

After a lapse of two intervals of time ($2t$), the first block will have travelled to a distance

$$L_2 = 2t\cdot\sqrt{\frac{P\,.\,a}{m}} + l - a\left(\frac{\pi}{2} - 1\right).$$

while block 2 has travelled a distance L_1, the increased distance between the two being

$$L = t\sqrt{\frac{P\,.\,a}{m}}.$$

After lapses of n intervals of time n blocks will have been released, and will be separated from each other by distances L. As there are now no external forces acting in these blocks, they will continue to occupy their relative positions, and may therefore be looked upon as one object.

Before enquiring into the question of speed, it is desirable to explain the meaning of the product $P\,.\,a$; this is twice the energy stored up in the spring, and, as regards any of the above results, it is clear that it makes no difference whether P, the pressure of the spring, is constant until spring 1 leaves block 2, or whether it gradually diminishes to nothing when separation takes place, that being the case illustrated above; nor is it necessary that separation should take place, provided only that the total energy expended by the spring is $\frac{P\,.\,a}{2}$. Assuming now that separation does not take place, and that the pressure P diminishes to O, then

$$L = a = t\sqrt{\frac{P\,a}{m}}.$$

This is true, however small we make the distance $(l+a)$, provided t is reduced in proportion, nor does it make any difference if, instead of a block and spring, we use elastic blocks in contact with each other. This is of course the

case of a long elastic bar or plug, which is the subject we wish to deal with.

In such a bar, P is the pressure exerted when a length $l+a$, is reduced to l, in other words $P=\frac{E.a}{l+a}$ where E is the modulus of elasticity, and the bar is supposed to have unit cross section. Let m be the mass of a bar of the length $(l+a)$, μ being the mass per unit of length, then we have

$$m=\mu.(l+a) \text{ and } V=\sqrt{\frac{E.a^2}{\mu.(l+a)^2}}=\sqrt{\frac{P^2}{\mu.E}},$$

where V is the velocity of propagation of a pressure-wave in the plug.

That this is true for the whole bar of unit length, as well as for its individual parts, is easily shown. The shortening of a bar of unit of length, under a pressure P, is $\frac{P}{E}$. The work done, or energy stored, is $\frac{P}{2}\cdot\frac{P}{E}$ per unit cross section, and this is equal to the product $\frac{V.^2\mu}{2}$, which leads to identically the same result as above, and which means that the energy stored in a stretched or a compressed bar when stationary, is equal to the *vis viva* of the unstrained bar when released and moving.

We have now to ascertain the velocity W with which the pressure-wave travels along the bar. It will differ, of course, according as to whether we deal with the length l of the shortened bar, or with $l+a$ its natural length, for the time t is the same in both cases. This time has already been determined under the conditions that when free successive elastic blocks are just touching, then

$$t=a\sqrt{\frac{m}{P.a}},$$

and W the velocity with which the pressure-wave travels in the unstressed bar is

$$W = \frac{l+a}{t} = \frac{l+a}{a} \cdot \sqrt{\frac{P \cdot a}{m}} = \frac{E}{P} \cdot \sqrt{\frac{P^2}{E \cdot \mu}} = \sqrt{\frac{E}{\mu}}.$$

This, as is well known, is the velocity of sound in an elastic bar, E being the dynamic modulus of elasticity, and μ the mass per unit of length and cross section.

$$\frac{W}{V} = \frac{l+a}{a} \sqrt{\frac{P \cdot a}{m}} \sqrt{\frac{m}{P \cdot a}} = \frac{E}{P}.$$

We are now in possession of the principle which governs the phenomena of blows.

Suppose that a bar of steel of one-inch sectional area were dropped on a rigid anvil with a velocity V of 10 feet per second, then, as

$$W = \sqrt{\frac{30{,}000{,}000 \,.\, 32{\cdot}2 \text{ ft.} \,.\, 12 \text{ ins.}}{0{\cdot}277 \text{ pounds}}} = 204{,}000 \text{ inch} = 17{,}000$$

feet per second, we have

$$P = E \,.\, \frac{V}{W} = 30{,}000{,}000 \,.\, \frac{10}{17{,}000} = 17{,}650 \text{ pounds} = 7{\cdot}9 \text{ tons.}$$

It will be noticed that the pressure of the blow is quite independent of the length of the bar. If a rod moving with a velocity V comes in contact with a solid, its front end is of course brought to rest at once, but its tail end is still moving forward with a velocity V until the pressure-wave has reached this point, then the whole bar is at rest; but an instant later the tail end is moving off again with a velocity V due to the pressure P, and a wave of negative velocity is now travelling towards the anvil. As soon as this is reached the whole bar is travelling away from the anvil with a velocity V. This is a simple case of an elastic blow.

We have already found the pressure of a blow. The duration of a blow is equal to the time which the pressure-

wave takes to travel from one end of the bar to the other and back again. In the above case

$$t = \frac{2 \cdot L}{W} = \frac{2 \text{ feet}}{17{,}000} = \frac{1}{8{,}500} \text{ second.}$$

The duration of the blow is therefore independent of the velocity of the moving object.

We can now enquire into Dr. Hopkinson's three experiments. His wires were suspended from a beam (see *Fig.* 7), their tenacity appearing to have been 54,400 lbs. and 80,000 lbs. He assumed the modulus of elasticity to be 25 millions, whereas 30 millions is probably more correct for iron and steel. Weights of 56 lbs. and 61 lbs. were attached to the bottom of each wire, and, at some little distance above, a clamp weighing 1 lb. 10 oz. (no details were given in the first experiment) was firmly attached to each wire. Weights of 7, 16, 28, and 41 lbs. were dropped on this clamp from various heights. A velocity V would be imparted to the clamp, producing a pull, $P = E\frac{V}{W}$, both above and below the clamp; the upper pull would travel to the point of suspension and would be reflected downwards; at this point, therefore, and as far as the return wave has travelled, the pull would be twice as great as at the clamp. If, therefore, P was just not intense enough to tear the wire near the clamp,

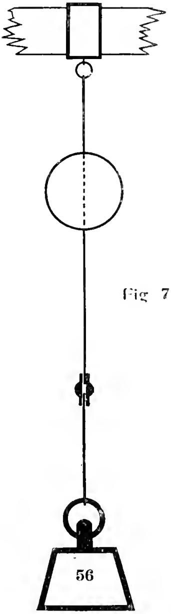


Fig 7

it might be intense enough to tear it close to the beam, the velocity V, which would produce rupture indifferently either at the top or bottom, would in the first experiment be

$$V = \frac{54{,}400 \cdot 17{,}000}{30{,}000{,}000} = 30{\cdot}8 \text{ feet per second,}$$

corresponding to a height of fall of 14·8 feet.

In the second and third experiments we have

$$V = 45{\cdot}3 \text{ feet, height} = 32 \text{ feet.}$$

Dr. Hopkinson gives the observed heights, and he also corrects these heights on the assumption that the blows of the falling weights on the clamp were plastic ones (*see* column 3); it is, however, more reasonable to suppose that the blows were elastic, or, more correctly, that during contact of the weight and clamp the velocity would be V, but as soon as the two objects had separated again, the velocity of the clamp would be almost twice as great as that of the ball, and the theoretical height of fall could be diminished to nearly one quarter. The pressure-wave in the wire would therefore consist of a short length corresponding to V, followed by a longer one corresponding to

$$2V \cdot \frac{M}{M+m}.$$

The corresponding height is given in column 4 (" calculated height for elastic blow.")

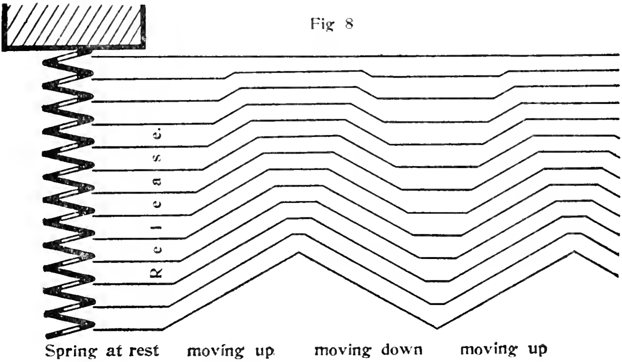
Strange to say, Dr. Hopkinson's first experiments agree fairly well with this view, but the second and third sets are not satisfied either by this or the previous supposition. The discrepancy must be accounted for by the plasticity of the material, energy being absorbed by the plastic stretch.

Falling Weights.	Calculated Heights.			Observed Heights.
	Direct Blow.	Plastic Blow.	Elastic Blow.	
Pounds.	Feet.	Feet.	Feet.	Feet.
FIRST EXPERIMENTS.				
$7\frac{1}{4}$	14·8	22·0	5·5	6·5 to 7·0
28	„	16·5	4·1	5 to 6
41	„	16·0	4·0	4·5 to 5·5
SECOND EXPERIMENTS.				
7	32·0	48·5	12·2	81 to 84
16	„	39	9·7	81
28	„	36	9·0	78 to $79\frac{1}{2}$
THIRD EXPERIMENT.				
28	32·0	36	9·0	60 to 63

These experiments have an important practical bearing on the question of steam-pipe explosions as shewing that, when the material receiving a blow is of a plastic nature, the blow is materially weakened in its effects. Dr. Hopkinson's experiments do not prove that it requires twice as great a velocity to tear a wire at the bottom as it does to tear it at the top, nor is it possible, except with a brittle material (as, for instance, glass), to demonstrate this deduction. I therefore arranged the following experiment. A helical spring 1·40 inch diameter, consisting of 268 turns of pianoforte wire 0·056 inches thick, was suspended from a beam, the bottom was held down by means of a very fine cotton thread, and was released by burning it. At the same instant a photographic camera on a revolving stand was set in motion. The bright reflections of each turn of wire should have produced

lines on the photographic plate, but apparently the vibrations were too rapid, and the indications are too faint to be reproduced. *Fig.* 8 represents what took place, only, of course, the lines are less numerous and further apart than in the experiment. At first, each turn of wire would produce a photographic horizontal line, then, after the release, as the pressure wave travelled upward, one coil after another would move upwards at a uniform velocity, would then remain stationary, and would then move down, &c.

Fig 8



The diagram shows what happened, and the spring, which I will now release, will give an idea of the jerkiness of the motion.

The lower end of the spring can clearly be seen to reverse its motion suddenly; in fact, these reversals are so sudden as to suggest hammer blows. At any higher point one can see how the turns of wire are sometimes stationary, sometimes moving up, sometimes moving down.

The duration of a complete up and down travel of the pressure in the above spring, *i.e.*, across 536 coils, should be

$$t = 2\sqrt{\frac{q}{Q.(g.12'')}} = 2\sqrt{\frac{1}{0\cdot018.386\cdot4}} = 0\cdot82 \text{ seconds}$$

where q is the weight of the spring, Q the weight which will produce an extension of one inch, and 386·4 is the acceleration due to gravity in inches. It was found somewhat difficult to time the oscillations of the spring before its vibrations are changed into undulatory ones, but there seem to be about four complete vibrations in five seconds, which is in fair agreement with the value found above.

This spring will also show very clearly that several positive or negative changes of motion can travel together along its length, independently of each other. This is a matter of great importance, for it supports the views often expressed by Dr. König, whose recent death we all deplore, that musical *timbre* is as much a matter of the shape of sound-waves as of combination of several systems of undulatory waves, a view underlying Helmholtz's analyses.

As a sudden change of motion is quite contrary to our ideas of acceleration, an additional explanation of the phenomena exemplified in this spring is perhaps not out of place. A force imparts a given velocity to a given mass in a given time. If the force is of a fixed intensity, then the velocity will also be fixed, provided the mass and time are proportioned to each other. Now, the mass of the very extreme end of the spring can be imagined to be infinitely small, therefore, the time in which it acquires or changes its velocity under the influence of a definite pressure must also be infinitely small.

From the above it is, I think, now quite clear that, when an elastic body suddenly comes to rest, the pressure exerted by it can be calculated by the formula already found

$$P = E\frac{V}{W},$$

and the duration of the pressure is

$$t = \frac{L}{W};$$

this is true not only for an elastic bar falling on an anvil, but also for a plug of water in a pipe if it be moved at a velocity V and then suddenly stopped. Thus, in the glass pipes which I intend to burst to-night, we have a partial vacuum about 2 feet long on the one side of a plug of of water 6 inches long; by breaking off the small projecting glass tube at the water end the plug is suddenly exposed to atmospheric pressure, and is propelled towards the other end. The mass per square inch of sectional area of this plug is about [illegible]. The velocity acquired while travelling a distance of 2 feet is therefore about 94 feet per second, and the pressure, which in a fluid naturally acts in every direction (hydrostatic), is

$$P = E \frac{94}{W} = \frac{320,000 \cdot 94}{4,700} = 6,400 \text{ pounds per square inch.}$$

Here W is the velocity of sound in a cylinder of water, and E is the volume elasticity of water in pounds per square inch.

It will thus be seen that the pressure which can be produced is so excessive, that not only will it fracture the glass tubes, but it will carry the glass splinters to a considerable distance, and if the pipe were of steel, one might expect at least a swelling to take place at the closed end.

We have in this experiment a reproduction of a steam-pipe explosion, illustrated as *Fig.* 2, taken from the Board of Trade Report No. 594. The valve on the boiler was being opened when the pipe just above the steam hammer exploded. Here, evidently, water had settled above the boiler valve and was shot over as in the experimental glass tube. Similar explosions are detailed in a few other Board of Trade Reports.

Several explosions have occurred near intermediate stop-valves, probably caused by a plug of water travelling

along a pipe and meeting with an obstruction. To reproduce this condition, my assistant, Mr. Baron, has prepared a pipe with water pockets, on breaking off the end and admitting air behind the lowest plug of water the pipe is shattered at the first water pocket. This experiment also clearly shews that the pressure caused by the impact acts in all directions.

At the conclusion of this paper, I intend to reproduce experimentally the conditions set up in the cases illustrated in *Fig.* 1. A glass tube bent like an L is connected at its top end with a flask in which steam is generated. This represents the boilers at work, the other end is closed with an India-rubber stopper, representing the stop valve of the boiler about to be connected to the main steam pipe. The customary drain cock is attached here. As soon as steam is got up and the water in the pipe lowered, a violent commotion is set up, which is accompanied by water-hammer blows, and these would drive out the India-rubber stopper if air cushions had not been left in the water. Reports on accidents of this class are very numerous.

In order to ascertain the stresses set up in the walls of steam pipes subjected to water-hammer action, it would be necessary to retrace our steps and to repeat the above investigation, not for the elastic, but for the plastic, condition of materials; and, as we know as yet little about plastic stresses, we should even have to discuss the very probable possibility of these stresses being functions of the durations of blows; when this has been done, and experiments similar to those of Dr. Hopkinson have been repeated, we shall be in a position to decide what influence the various materials of which steam-pipes are made have on the stresses produced by water-hammers. To go into these matters, however, would enlarge this subject too much.

Manchester Memoirs, Vol. xlvi. (1901), *No.* **4.**

IV. Preliminary Note on the Preparation of Barium.

By EDGAR STANSFIELD, B.SC.

(*Communicated by* R. S. HUTTON, M.SC.)

Received and read October 29th, 1901.

Many attempts have been made to prepare metallic barium, but, up to the present, no satisfactory method of obtaining it seems to have been described. There is a general lack of chemical analyses of the products obtained by the various workers, even when they profess to have obtained the metal.

In view of the satisfactory solution by Moissan* of the difficulties of preparing the allied metal calcium, which can now be obtained in a pure state, I decided to undertake a critical study of the hitherto proposed methods of preparing barium, in the hope of finding some modified or new process which would give good results; care being taken to check each step by as accurate a chemical analysis as possible.

At present I propose to consider three of these:—

1. *Method of Distillation of Amalgam*: My results are here in accordance with those of the more modern experimenters.† I found that, although it is easy to prepare a solid crystalline amalgam, containing nearly 5 per cent. of barium, by means of the electrolysis of a saturated solution of barium chloride, using a mercury

* *Ann. Chim. Phys.* (7) xviii. (1899), p. 289.

† Kern, *Zeits. anorg. Chem.*, xvii. (1898), p. 284; also xxv. (1900), p. 1; Langbein, "Inaugural Dissertation," Königsberg (1900).

cathode, I was unable to remove all the mercury from this amalgam by distillation *in vacuo.* It is very difficult to completely dry the amalgam, without oxidation occurring.

2. *Method for Preparing Zinc Alloys*: I have tried two methods for this preparation. The first which consists in electrolysing a fused mixture of barium and sodium chlorides with a molten zinc cathode, was wholly unsuccessful; the second, which is the method used by Caron,* yielded better results. In the best experiments I took 210 grams zinc, 20 grams sodium, 120 grams barium chloride (20 grams sodium being equivalent to 90 grams barium chloride); I also added 25 grams of sodium chloride as a flux. This mixture was heated in a fire-clay crucible until it boiled, and was then allowed to cool. A porous metallic mass was obtained weighing 250 grams, analysis showing that this contained 12 per cent. of barium, as well as traces of chlorides and oxides; but that at least some of the barium was present in the metallic state, was shown by the freedom with which it decomposed water, especially after it had been powdered.

This product did not seem pure enough to be likely to give good results on distilling off the zinc. The disadvantage of the method of distilling off the mercury or zinc from the amalgam or alloy of barium, seems to be that, at the best, only a product of finely divided material can be obtained; such powdery masses are of very indefinite composition, and, presenting as they do so much surface to the action of the surrounding medium, offer considerable difficulty to the working-up of a satisfactory product from them.

3. *The "Goldschmidt Process"*: It appeared therefore advisable to find some method which would give a fused product, such product being likely to have a more

* *Comptes Rendus*, xlviii., p. 440.

homogeneous composition. Since barium evidently has a rather high melting point, such a process must be one carried out at a high temperature. The Goldschmidt process, whereby oxides are reduced by means of finely divided aluminium mixed with them in an intimate manner, and in which the heat of the reaction, being very large, is generally sufficient to fuse even the alumina formed, was considered likely to give interesting results.

The experiments had to be carried out under reduced pressure, both in order that the charge should not be scattered about by the sudden expansion of the air, due to the rise of temperature, and to prevent loss owing to the formation of barium oxide and nitride, the ease with which these compounds are formed being a great hindrance to all attempts to prepare the metal in the atmosphere.

Description of Apparatus: Crucibles of Veitsch magnesite of about 200 cc. capacity were employed ; these do not seem to be acted on during the experiment. One crucible generally lasted for two or three experiments before it broke up owing to the sudden changes of heat. Lids were made out of powdered Veitsch magnesite with magnesium chloride solution. The crucible was strengthened by being surrounded by a sheet-iron jacket, and the lid was held down on to the crucible by two brass plates, one below the crucible and the other on the top of the lid, these plates being tightly screwed together by means of three bolts. The crucible, thus encased, was placed inside an iron vessel, over which another iron vessel, inverted, was placed, this being a precaution for the safety of the bell-jar desiccator, inside which the whole apparatus was finally put. Undue heating of the iron vessels by conduction was guarded against by means of asbestos millboard.

The charge (described below) is fired by the following contrivance: through the sides of the crucible, and near the bottom, were drilled two holes opposite to each other; two aluminium wires were passed through these and joined inside by a bridge of fine platinum wire, which passed through the centre of the starting charge. The aluminium wires were connected by binding screws to two lengths of insulated copper wire, which passed airtight through the stopper of the desiccator. To fire the charge, an electric current of 2-3 ampères was passed through the wires, the platinum wire becoming hot enough to start the reaction.

In the earlier experiments the charge consisted of barium oxide and aluminium, together with a starting charge of barium peroxide and aluminium. It was afterwards found to be more satisfactory to use nothing but the peroxide and aluminium; for not only can the peroxide be obtained in a purer condition, but, the heat of the reaction being greater, a better-fused mass is obtained. The aluminium used was in fine granules, except round the platinum wire, where the flake aluminium was used; it is necessary to strongly heat both sorts before use, in order to drive off the fatty matter with which they are always contaminated.

In an actual experiment, all the chemicals to be used and the crucible are strongly heated, and allowed to cool in a desiccator, the charge is then weighed out, and the apparatus fitted up as rapidly as possible to prevent absorption of moisture. The bell-jar desiccator containing the apparatus is then exhausted by means of a water pump, and the charge fired.

After the apparatus has cooled, there remains a grey mass, at the bottom of the crucible, which usually contains crystalline flakes of a silver-white metal.

Both the grey mass and the metallic particles decompose water very rapidly. In dry air they do not change, but in moist air they rapidly crumble up, forming a white powder, while if heated in a blowpipe flame they first scintillate slightly, but then becoming coated with oxide they suffer no further action, nor are there any signs of fusion.

In the best experiment, the charge consisted of 100 grams of barium peroxide, 21 grams of aluminium (these being in the proportion required by the equation $3BaO_2 + 4Al = 3Ba + 2Al_2O_3$) together with 25 grams of the product of a previous experiment. The product in this experiment was a very hard, almost black, mass, which however was in parts very rich in crystalline flakes of metal, and also contained some small nodules of metal.

The metallic part contained 63·3 per cent. barium, but only 19·3 per cent. aluminium, the total being 82·6 per cent. An analysis in another experiment showed 66·6 per cent. barium, 29·3 per cent. aluminium; total 95·9 per cent.

The analysis of the nodules mentioned above, whilst it gave but 58 per cent. barium, was the only case in which the full 100 per cent. of barium + aluminium was reached; usually it was impossible to completely separate the flakes of metal from the associated oxide for the purpose of analysis, as the metal was so very brittle.

These experiments seem to indicate that the reaction is reversible, and that it cannot be used to obtain pure barium, but only an alloy of barium with aluminium containing up to about 60 per cent. barium.

An endeavour was made to prepare a calcium alloy by this method, but the reaction would not proceed at all. It was also attempted to replace the aluminium by magnesium; in this experiment, the charge taken was

only 14 grams magnesium and 48 grams barium peroxide, but the reaction was violent and shattered the bell-jar.

I hope to study other methods of preparation, more particularly the electrolysis of barium compounds.

The above work was carried out in the Electro-Chemical Laboratory of the Owens College.

EXPLANATION OF PLATE 9.

Fig. 1. Vertical section of crucible.
" 2. Horizontal section through AB.

C. Crucible.
D. Lid.
E and F. Brass plates.
H. Bolts.
J. Jacket for crucible.
K. Asbestos millboard.
L. Aluminium wires
M. Platinum wire.
N. Insulated copper wires.
O and P. Iron vessels.
R. Desiccator.
S. Bed-plate of desiccator.

Fig. 1

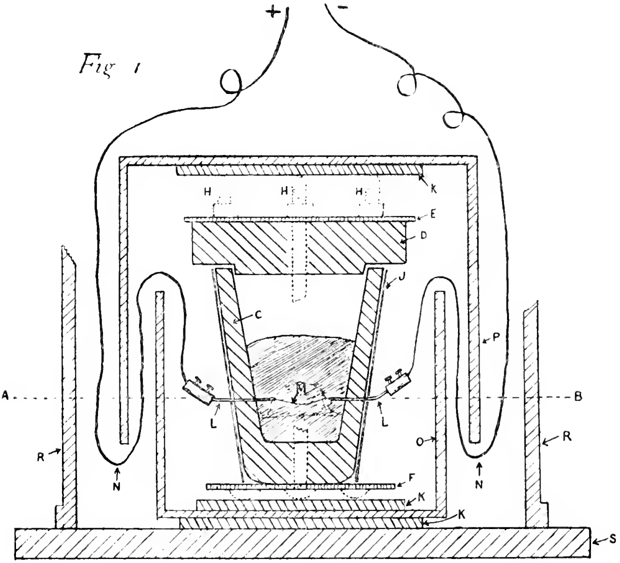
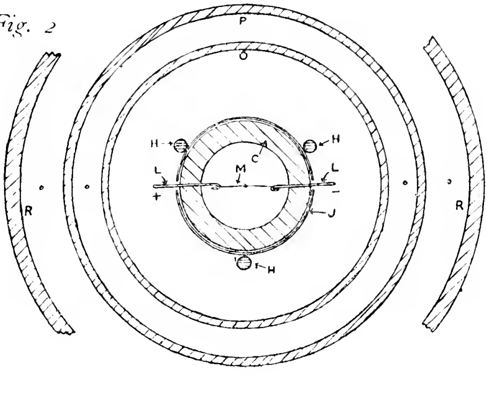


Fig. 2



Manchester Memoirs, Vol. xlvi. (1901), *No.* **5.**

V. On the Measurement of High-Pressure Explosions.

By J. E. PETAVEL,

Harling Fellow of the Owens College, Manchester.

Received and read November 26th, 1901.

The study of the phenomena which take place during an explosion is of considerable importance both from a theoretical and practical point of view. An exact knowledge of the variation of pressure will provide information on the rate of cooling of gases under high pressures, on the variation of specific heat at high temperatures, and on the question of dissociation.

From a practical point of view, such information is needed in the design of modern artillery and in all problems connected with ballistics. It enables the civil engineer to select the explosive suitable for the purpose to be attained. It guides the mechanical engineer in the design of the heat engine.

It is impossible in the present paper to do more than enumerate the principal devices which have been used for the measurement of explosive pressures. The first systematic experiments were carried out by Robins in 1743, Hutton in 1778, and Count Rumford in 1797. Rumford's method consisted in determining the minimum weight required to prevent a valve from lifting under the pressure of the explosion, and was used with slight variations by a long succession of investigators, the best known experiments being those carried on by Bunsen in 1867.

February 10th, 1902.

The relative strength of solid explosives was in those early days also estimated by the two following methods :—

I. Firing them in a closed chamber in the centre of a block of lead, the permanent increase of volume of the chamber being taken as a measure of the explosive force.

II. Measuring the angle through which a heavy pendulum was moved when acted upon by the explosion.

The next important advance was due to Rodman, who, in 1859, invented the crusher gauge. This instrument has been almost exclusively used during the last fifty years. A piston works in a steel cylinder screwed into the explosion chamber. One end of the piston is flush with the inner surface of the explosion chamber, the other rests on a short copper cylinder. The explosion crushes the copper by an amount which bears a known relation to the maximum pressure attained.

In 1875 Noble and Abel measured the explosive pressure of gunpowder by determining the rate of acceleration of a projectile.

In recent years many new instruments have been devised. Le Chatelier and Mallard have used a modification of the Bourdon gauge; Vieille has used a piston controlled by a stiff spring; Noble and others have obtained records from an instrument not unlike an ordinary steam-engine indicator, the initial compression of the spring being, however, regulated to nearly correspond with the maximum explosive pressure.

Many useful results have been obtained by causing the piston of the ordinary crusher gauge to inscribe its rate of motion on a revolving cylinder.

Finally, the chemical phenomena which occur during the firing of the charge, and the rate of the explosion of

several gaseous mixtures, have been most carefully studied by M. Berthelot in France, and H. B. Dixon in this country.

The all important condition for a gauge destined to record the rise and fall of pressure caused by an explosion is that its time period should be as small as possible. If A represent the force required to produce unit deflection of the vibrating system, W the weight of the moving parts, the time period will be

$$= 2\pi\sqrt{\frac{W}{Ag}}.$$

We have therefore two variables at our disposal, namely, the weight of the moving parts and the controlling force. The former must be made a minimum, the latter a maximum.

In most instruments where a short period is desirable, the strains to which the parts are subjected are very small, and the desired result is obtained by decreasing the size of all moving parts, and using, wherever possible, materials of low density. This method is employed in the case of all oscillographs, telegraph recorders, phonograph receivers, galvanometers, etc.

In the present case, the instrument having to withstand pressures of ten or twenty thousand pounds per square inch applied with extreme suddenness, strength becomes a condition of vital importance, and steel is the only material which will withstand the strain. We cannot, therefore, use materials of small density, neither can we reduce the dimensions of the moving parts below a certain limit.

It is thus evident that we must have recourse to the second variable factor to secure the short time period which is necessary. As we have seen above, the controlling force brought into play per unit length of motion must be as great as possible. In other words, we must use the stiffest spring we can obtain.

The stiffness of a spring will vary with the material of which it is made and its shape, increasing for a given size as the shape approaches more nearly to that of a solid bar subjected to longitudinal strain. This bar can be made as short as may be desired, and, in theory, the time period of the system is only limited by the density of the material and by its modulus of elasticity.

In practice, however, the travel of the moving parts cannot be indefinitely decreased, for the deflections must remain of such dimensions as to be accurately measurable.

The following figure represents a recorder designed on the principles we have just established.

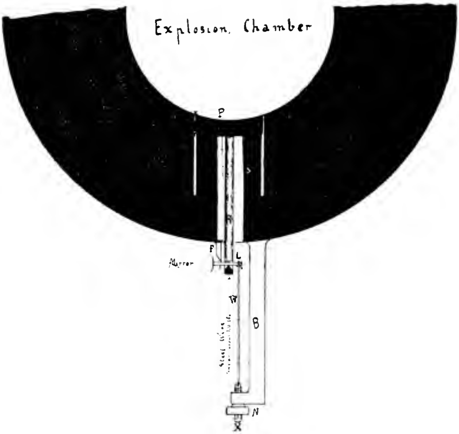


Fig. 1.

Diagrammatic Representation of the Recording Manometer.

A cylindrical groove is cut half through the walls of the enclosure. The upper part P of the cylinder thus obtained represents the piston of our indicator, and the lower portion S the spring. Under the pressure of the

explosion, the piston *P* will be forced outwards a certain small amount corresponding with the elastic compression of the material of which the spring is made. This motion is transmitted to the exterior by the rod *R*.

The lever *L*, supporting the mirror, rests on the fulcrum *F* at "3"; it is kept against the knife edge "2" of *R* by the tension of the wire *W*. The wire *W* is of considerable length, and is stretched to near its limit of elasticity. The lever *L* can, therefore, follow the small advance of the rod *R* without greatly diminishing the tension of the wire *W*.

The mirror focuses a point source of light on to a rapidly revolving cylinder, thus recording on a magnified scale the motion of the piston *P*. It is not impossible that an indicator of this type would work in practice, but the deflection of the mirror, and therefore the scale of the records obtained would be much too small. To increase the deflections three modifications are necessary—the spring *S* must be made longer, the ratio of its cross-sectional area to that of the piston be decreased, and the knife edges "2" and "3" be brought closer together.

In *Fig. 2* the design of the actual instrument is given, the lettering being the same as in the previous figure.

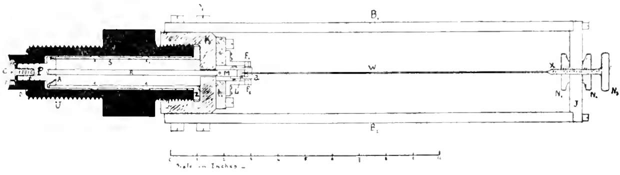


Fig. 2.

Section of Recording Manometer for High-Pressure Explosions.

By means of the thread *U*, the gauge screws into the explosion chamber, *C* being flush with the inside surface.

An air-tight joint is formed by the ring D pressing against a flat ledge.* The end of the gauge from D to E is a good fit in the walls of the explosion chamber, and the joint is thus protected from the direct effect of the explosion.

The spring S, about 5 inches in length, is tubular in shape. To prevent any buckling, it is made to closely fit the cylinder, in which it is contained, at two places, e_1 and e_2. The spring is fixed at the outer end Z, being held in place by the nut K; at the inner end it is free, and supports the piston P. The ordinary U leather is replaced by a leather washer, attached to the piston by the screw C and to the fixed part of the gauge by the rim E. The end of the piston projects about one-hundredth of an inch above the rim H, and it can therefore move back without straining the leather.

The mirror (not visible in the figure) is carried by the lever L. This lever is so designed that the knife edges 1, 2 and 3 (see *Fig.* 1) are in the same plane, it being at the same time possible to bring the knife edges 2 and 3 within one-hundredth of an inch of each other, should so great an amplification be found necessary. Up to the present, however, the distance has not been decreased below one-sixteenth of an inch, the scale obtained with this distance being found satisfactory.

With regard to the chronograph, there is but little to be said; the films on which the deflections are photographically recorded are wound on a drum which is kept in rapid rotation by an electric motor, the usual devices being used to regulate and measure the speed. The drum

* NOTE.—In the case of apparatus designed for gases under high pressures, all joints should be made directly metal to metal, no packing being used. A joint thus made, if properly designed, is and remains absolutely air-tight. It can be made or broken in an instant, and as many times as may be required.

is enclosed in a light-tight box, a long narrow slit (about $\frac{1}{32}''$ width) runs the entire length of the box parallel to the axis of rotation. One of the filaments of an incandescent lamp is focused by the mirror on to this slit, forming a fine straight line perpendicular to the axis of rotation and to the slit. The sharp point of light thus formed on the film moves from right to left as the pressure increases. To secure the quality and intensity of light which is necessary, the lamp is run at twice its normal voltage at the moment of the explosion.

To avoid the blurring of the zero line, the light is cut off an instant later, and the zero marked in when the products of the explosion have had ample time to cool to atmospheric temperature.

The gauge is calibrated by hydraulic pressure, and the results are checked by comparison with the values of the maximum pressure obtained by the statical method described at last year's meeting of the British Association*.

For each explosive mixture two records are taken, one at a high speed giving the rise of the pressure, the other at a low speed giving the rate of cooling.

Curves typical of these two records are given in *Figs.* 3 and 4 (*Plate* 10)†; they refer to a mixture of air and coal gas, fired at an initial pressure of about eleven hundred pounds per square inch. Oxygen was slightly in excess, the residual gases containing about two per cent. of it.

In tracing out diagrams like these, no part of the instrument, except the light frame carrying the mirror, moves more than one- or two-thousandths of an inch.

* *Report Brit. Assoc.*, 1900, p. 655.

† The original films can be measured to about one-thousandth of an inch; the prints given in *Figs.* 3 and 4 have lost somewhat in sharpness, but are still sufficiently good to give a fair idea of the records.

In spite, therefore, of the suddenness of the rise in pressure, the velocity of the moving parts remains small, and the usual trouble due to inertia does not arise. *Fig.* 3 (*Plate* 10) is an illustration of this fact; at *A* the pressure is rising at the rate of over a million pounds per square inch per second, none the less the curve turns sharply at nearly a right angle, without any sign of vibration. The necessary data with regard to *Figs.* 3 and 4 (*Plate* 10) will be found in Tables I. and II.

It is intended to obtain similar curves covering a range of pressure up to 20,000lbs. per square inch, and referring to mixtures from the most explosive to the non-explosive. The work will be divided into four parts, namely: I., Oxygen and hydrogen; II., Coal gas and air; III., Other gaseous explosive mixtures; IV., Solid and liquid explosives.

With regard to coal gas and air, barely half the work has as yet been finished; it is, therefore, too soon to draw any general conclusions. A few points, however, in the records here given deserve attention.

1. The time required to reach the maximum pressure, namely, 0·058 second, is not far from that which would be required with the same mixture at atmospheric pressure.

2. The ratio of explosive to initial pressure has been increased. At or near atmospheric pressure the ratio for this mixture would be about 7, in the present case it is 8·5. This fact is due to three causes which work simultaneously, namely, (*a*) the departure of gases from Boyle's Law; (*b*) the relative decrease of thermal loss during the time occupied by the combustion; (*c*) the increase in the absolute temperature at which dissociation would take place.

3. The rate of cooling has greatly decreased.

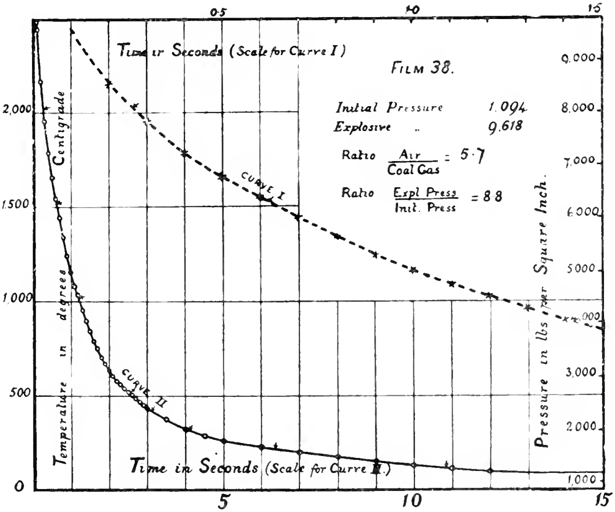


Fig. 5.

Rate of Cooling of the Products of Combustion.

The quantity of heat dissipated per unit of cooling surface increases with the temperature interval and with the pressure of the gas, but not at the same rate as the latter. The heat developed, on the other hand, is simply proportional to the pressure.

By increasing the pressure from one to 70 atmospheres, we increase the heat generated in a given volume 70 times, but we do not increase the rate at which heat is dissipated in anything like the same ratio. The increase of efficiency, which, in the case of gas engines, has always been connected with the use of high initial pressures, is mainly due to this cause. It is also, to some extent, due to the higher temperature obtained, and to the smaller dimensions of the moving parts.

One more point deserves attention. It will be noticed that, 0·05 second after firing, the rate of pressure suddenly increases, the rate of rise being over nine times as fast as before. For the less explosive mixtures this change in curvature does not occur, the curve of rise of pressure being similar to the cooling curve, only of course much steeper. It is worthy of note that the change of curvature occurs when the gas is at a mean temperature about equal to that at which spontaneous ignition would take place. A similar result would therefore be obtained if we heated the gases by the combustion of a certain portion of them until the entire bulk was at the "flash point;" the combination would then take place simultaneously throughout the entire mass, resulting in an almost instantaneous rise to the maximum temperature and pressure.

Explosives may be divided into three classes—instantaneous, medium, slow—according to the speed at which the maximum pressure is attained. To the first class, comprising fulminate of mercury, nitro-glycerine, etc., the speed being equal to or above the natural period of vibration of solid bodies, the term "pressure" hardly applies, the phenomenon being not static but kinetic, of the nature of an impact and not a pressure. If the explosion takes place in a closed vessel, a certain pressure will follow the combustion, but this pressure is no measure of the stresses exerted. The second class would contain such explosives as ordinary gunpowder, cordite, and mixture of hydrogen and oxygen, the time of rise varying, according to circumstance, from 0·0001 to 0·01 second. Mixtures of air and coal gas, and the more diluted mixtures of hydrogen and oxygen, take their place in the third category, with speeds from 0·01 to 1 second.

Before closing, it should be stated that the present research has been greatly facilitated by funds awarded by

the Government Grant Committee of the Royal Society. This opportunity is taken to thank Professor Schuster for so kindly placing the ample resources of his laboratory at my disposal, whilst thanks are also due to the Committee of the Davy-Faraday Research Laboratory for the loan of certain parts of the apparatus. Lastly, it is only just to state that the satisfactory results obtained with the apparatus described are attributed to the care and skilled workmanship of Mr. Charles W. Cook.

TABLE I.

See *Plate* 10, *Fig.* 3. (Film 41, Explosion No. 181).
Spherical Enclosure, 4″ diameter.
Capacity, 551·91 c.c. = 0·0195 cub. ft.

Temperature of Enclosure before firing 18°C.
,, ,, after products of combustion had cooled 24°C.

Initial Pressure... ...	77·3 Atms.	= 1,136 lbs. per sq. inch.
Ratio of Air to Gas		= 6·0
Maximum Explosive Pressure	647 Atms.	= 9,508 lbs. per sq. inch.
Ratio of Maximum Explosive Pressure to Initial Pressure		= 8·4
Residual Pressure ...	63·8 Atms.	= 937 lbs. per sq. inch.

Analysis of Residue.

Carbon dioxide... ...	9·8%
Oxygen...	3·0%
Nitrogen	87·2%
	100·0%

TABLE I.—*Continued.*

Time in Seconds.	Reading in Millimetres.	Absolute pressure in lbs. per sq. in.	Absolute pressure in Atmospheres	Time in Seconds.	Reading in Millimetres.	Absolute pressure in lbs. per sq. in.	Absolute pressure in Atmospheres.
0·000	—	1136	77	0·058	21·99	9508	647
0·010	0·77	1237	84	0·060	21·91	9477	644
0·020	1·57	1549	105	0·062	21·91	9477	644
0·030	3·06	2130	145	0·064	21·67	9385	639
0·040	5·03	2898	197	0·066	21·63	9369	637
0·042	5·21	2968	202	0·068	21·60	9357	636
0·044	5·84	3204	218	0·070	21·56	9340	635
0·046	6·38	3424	233	0·080	21·22	9209	626
0·048	6·86	3612	246	0·090	21·07	9149	622
0·050	7·47	3850	262	0·100	20·87	9071	617
0·052	10·80	5147	350	0·150	19·73	8628	587
0·054	15·92	7143	486	0·200	18·61	8192	557
0·056	19·83	8667	590				

TABLE II.

See *Fig.* 4 (*Plate* 10), and *Fig.* 5 (Film 38, Explosion No. 175).
Spherical Enclosure, 4″ diameter.
Capacity, 551·91 c.c. = 0·0195 cub. ft.

Temperature of Enclosure before firing 21° C.
" " after products of combustion had cooled 27° C.

Initial Pressure... ...	74·38 Atms.	= 1,094 lbs. per sq. inch.
Ratio of Air to Gas		= 5·71
Maximum Explosive Pressure	654·2 Atms.	= 9,618 lbs. per sq. inch.
Maximum Temperature		= 2483°C.
Ratio of Maximum Explosive Pressure to Initial Pressure		= 8·8
Residual Pressure ...	58·98 Atms.	= 867 lbs. per sq. inch.

Analysis of Residue:

Carbon dioxide ...	11·2%
Oxygen	2·0%
Nitrogen	86·8%
	100·0%

TABLE II.—*Continued.*

Time in Seconds.	Reading in Millimetres.	Absolute pressure in lbs. per sq. in.	Temperature of gas in degrees Centigrade.†	Time in Seconds.	Reading in Millimetres.	Absolute pressure in lbs. per sq. in.	Temperature of gas in degrees Centigrade.†
0·08	23·54	9618	2483	2·2	5·68	2979	581
0·1	23·19	9487	2445	2·3	5·54	2927	566
0·2	20·55	8506	2164	2·4	5·32	2845	542
0·3	18·62	7789	1957	2·5	5·13	2774	522
0·4	16·95	7167	1781	2·6	5·00	2726	508
0·5	15·83	6751	1661	2·7	4·83	2663	490
0·6	14·78	6361	1548	2·8	4·68	2607	474
0·7	13·79	5993	1445	2·9	4·51	2544	456
0·8	12·82	5632	1341	3·0	4·35	2484	439
0·9	11·92	5298	1245	3·5	3·82	2287	382
1·0	11·08	4986	1156	4·0	3·33	2094	327
1·1	10·38	4726	1081	4·5	2·96	1968	291
1·2	9·72	4481	1011	5·0	2·72	1878	265
1·3	9·20	4287	955	6·0	2·47	1785	239
1·4	8·68	4094	900	7·0	2·16	1670	205
1·5	8·16	3901	845	8·0	1·95	1592	183
1·6	7·68	3722	793	9·0	1·74	1514	161
1·7	7·30	3581	753	10·0	1·54	1439	139
1·8	6·86	3418	706	11·0	1·43	1399	128
1·9	6·54	3299	672	12·0	1·32	1358	116
2·0	6·23	3183	639	15·0	1·15	1295	98
2·1	5·95	3079	609				

† The temperatures in this column are calculated in the usual manner from the pressure, allowing for the quantity of water vapour formed.

EXPLANATION OF PLATE 10.

Fig. 3. *Rise of pressure during the explosion.*

Spherical enclosure capacity, 551·91 c.c.
Temperature of enclosure: before firing, 18° C.
" " " : after firing, 24° C.
Initial pressure 77·3 Atms. (1,136 lbs. per sq. in.)
Maximum explosive pressure = 647 Atms. (9,508 lbs. per sq. in.)
Ratio: Air to gas = 6·0.
" : Explosive pressure to initial pressure = 8·4.

Fig. 4. *Fall of pressure after the explosion.*

Spherical enclosure capacity, 551·91 c.c.
Temperature of enclosure: before firing, 21° C.
" " " : after firing, 27° C.
Initial pressure, 74·38 Atms. (1,094 lbs. per sq. in.)
Maximum explosive pressure, 654·2 Atms. (9,618 lbs. per sq. in.)
Ratio: Air to gas = 5·71.
" : Explosive pressure to initial pressure = 8·8.

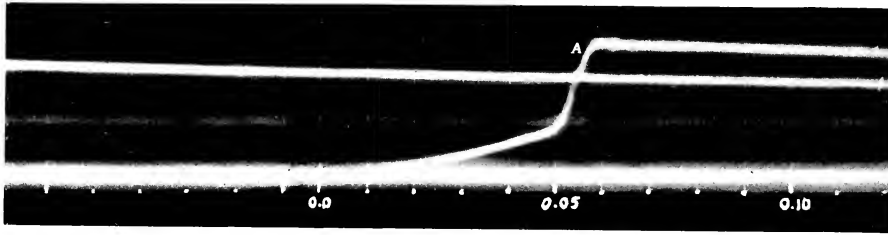


Fig. 3.—Rise of Pressure. Time in seconds.

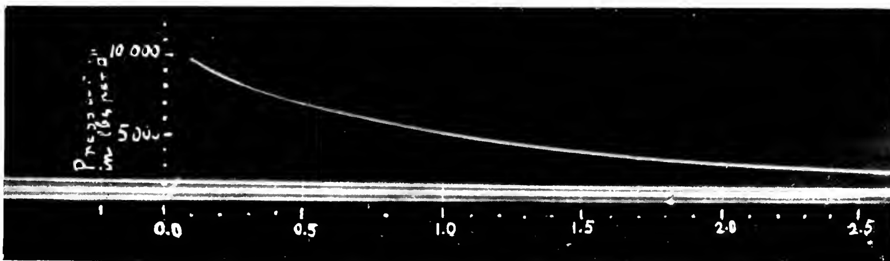


Fig. 4.—Fall of Pressure. Time in seconds.

EXPLOSION OF A MIXTURE OF AIR AND COAL GAS.

Manchester Memoirs, Vol. xlvi. (1902), *No.* 6.

VI. On the Fusion of Quartz in the Electric Furnace.

By R. S. HUTTON, M.Sc.

Received and read January 7th, 1902.

During recent years a good deal of attention has been paid to the working of fused quartz with a view to its use in the construction of apparatus.[1] Owing to the exceedingly small coefficient of expansion of this material[2] and to its high melting point, it would doubtless find many applications for making vessels in which to study the properties of substances at high temperatures, and especially for making high temperature gas thermometers. Further, since fused silica withstands very sudden changes of temperature without showing any tendency to crack, probably many industrial uses could be found for it as soon as a more economical method of fusing and working it is forthcoming. Up to the present, the oxyhydrogen blowpipe has been used almost exclusively, and, in the hands of Shenstone and Lacell and of Dufour, has led to very satisfactory and promising

[1] C. V. Boys, *Phil Mag.*, 1887.
H. L. Callendar. *Journ. Iron and Steel Inst.*, 1892, Vol. i., p. 165.
W. Crookes. "On the Spectra of Argon." *Phil. Trans., Vol.* 186 (A), (1895), p. 245.
R. Threlfall. "Laboratory Arts." 1898, esp. p. 199.
A. Dufour. *Comptes Rendus*, Tome CXXX. (1900), p. 775.
A. Gautier. *Comptes Rendus*, Tome CXXX. (1900), p. 816.
W. A. Shenstone. *Nature*, Vol. LXI. (1900), p. 540.
W. A. Shenstone and H. G. Lacell. *Nature*, Vol. LXII. (1900), p. 20.
W. A. Shenstone. *Proc. Roy. Inst.*, 1901. *Nature*, Vol. LXIV. (1901), pp. 65 and 126.

[2] H. Le Chatelier. *Comptes Rendus*, Tome CVIII. (1889), p. 1046, and Tome CXXX. (1900), p. 1703.
H. L. Callendar. *Vide* Shenstone, *Nature*, Vol. LXIV. (1901), p. 66.

results. The process is, however, expensive, and is also very slow, since the oxyhydrogen flame is at a temperature only slightly above the fusing point of silica, and, in fact, it is only at a certain point in the flame that the fusion can be carried out at all.

Moissan[1] has studied the effect of the electric arc upon silica, and has noted that it fuses and is easily volatilised, but he studied more particularly the reduction products, carborundum and silicon, which remain behind when silica is heated for some time in an electric furnace, and, according to Gautier, did not succeed in making apparatus of this material. Upon repeating Moissan's experiment on the volatilisation of flint stones as a lecture experiment, with an electric-arc furnace using 300 ampères at 50 volts, I was struck by the appearance of the residual unvolatilised silica, which was very glassy and in parts quite transparent. Experiments soon showed that, provided a small current of air is allowed to pass through the furnace, no reduction of the solid or liquid silica takes place, and, consequently, the arc can be used as a source of heat for fusing silica without fear of reduction spoiling the results.

At first apparatus was fitted up for obtaining an arc-flame from inclined carbons by magnetic deflection downwards; in this way the arc-flame was made use of much in the same manner as the oxyhydrogen flame, and rods could be made easily by the method recommended by Shenstone. It was soon found, however, that a small arc using 15-20 ampères was not sufficiently powerful to ensure rapid work, and, after working with a similar open arc, using about 50 ampères with separate circuit for the magnet, the furnace was again brought into use for fusing the quartz.

[1] H. Moissan. "Le Four électrique," 1897, p. 49.
A. Gautier, *loc. cit.*

Whilst employing the open arc, however, several interesting observations were made, which may be worth while recording.

In the first place, supports of carbon can be used with advantage for bringing the quartz into the flame, but it is necessary that the carbon used for these supports, as also the carbons used for the arc, be as pure as possible, or else the quartz may be contaminated by the ash which falls upon it ; for the supports I have throughout made use of graphitic carbon prepared in the electric furnace, which is very pure and easy to work ; it can, moreover, now be obtained on the market at a reasonable price.

In building up small rods, grooves were cut in a plate of this carbon and small pieces of prepared quartz were placed in these grooves, the quartz being melted together gradually from one end to the other of the grooves, by sliding the carbon plate gradually under the arc-flame. Small lens-shaped discs can be similarly prepared by placing pieces of the prepared quartz in a shallow carbon crucible, and, with a little practice, it is hoped that masses suitable for making lenses can be prepared in this way. The valuable optical properties of fused quartz are pointed out by Shenstone in his papers.[1]

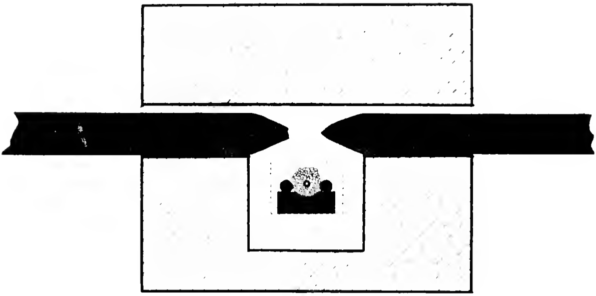
When quartz is thus fused in the arc, it is quite easy to observe the reduction which takes place in the immediate neighbourhood of the arc, and causes a black stain on the surface, which can easily be made to disappear by bringing the heated mass for a short time away from the centre of the flame ; in fact, the working of quartz in the arc-flame much resembles the working of lead glass in

[1] It should be mentioned that Messrs. Zeiss, of Jena, exhibited small lenses at the Paris Exhibition in 1900, made of "crystal de roche fondu," but the method by which the quartz was fused was not stated.

the ordinary blowpipe, except for the immense difference of temperature.

Owing to insufficient skill in the art of glass-blowing, and to the pressure of other work, I did not feel encouraged to proceed with these experiments with the open arc, but undertook a few experiments with the furnace which have led to promising results.

A Moissan arc furnace of the well-known type was modified by cutting passages in the sides, so that a carbon support charged with quartz could be passed under the arc and at right angles to it; a section of the furnace is seen in the accompanying figure.



SECTION OF ELECTRIC FURNACE.
(One-fifth natural size.)

In this way one certainly makes more use of the heat of the arc, since the reflection from the cover prevents a great part of the heat being lost, and magnetic deflection of the arc, which in this case was not made use of, might be found a further advantage for economical working.

A current of about 300 ampères at 50 volts was usually employed, and with this power the quartz was seen to melt on the surface within a minute or so of commencement. Nearly all the experiments with this form of furnace were arranged with a view to preparing

thick-walled tubes of quartz, with a core of about 1/8 inch. As seen from the figure, a rough mould was made of carbon with a carbon core, resting at each end on carbon supports. The mould was arranged usually for making tubes 10-12 inches long, but, obviously, any desired length of tube could be similarly constructed. The mould was filled with broken-up quartz of different degrees of fineness, but it was found that the best results were obtained when the quartz was not too finely powdered. The tubes obtained in this way can easily be separated from the carbon support and the core be withdrawn, since the silica does not adhere to the carbon.

Up to the present, I have not succeeded in preparing tubes quite free from bubbles, but the general appearance can be greatly improved by re-heating under the arc, preferably with mechanical rotation in order to get a more uniform result. Even in their present form, however, they would probably be of much use for constructing apparatus, as, owing to their thickness, there is plenty of material for blowing and drawing down purposes, and by this process the appearance of the material is, of course, much improved.

Pure white sand fused in a similar way always seems to give a much more opaque mass; but plastic quartz can take up a certain amount of sand without thereby impairing its transparency, and probably a small sand blast, blowing sand or fine quartz, could be used for thickening bulbs and tubes of quartz fused by this method.

It is to be hoped that those who have large power at their disposal will extend the application of this method, which may thus bring fused quartz apparatus within the reach of those wishing to make use of it in virtue of its interesting and valuable properties.

The experiments described in this paper were carried out in the Physical Laboratories at Owens College.

Manchester Memoirs, Vol. xlvi. (1902), *No.* 7.

VII. On the Failure of certain Cast Steel Dies used in the Manufacture of Drawn Tubes.

By George Wilson, D.Sc.,

Demonstrator in the Whitworth Engineering Laboratory, Owens College, Manchester.

Received and read January 7th, 1902.

In the manufacture of drawn copper tubes, it is usual to draw the tube through a somewhat tapering hole formed for this purpose in the centre of a cast steel die. By this means the tube is increased in length, diminished in area, and improved in quality. During this process, the dies may be placed under severe stress, and, as the nature of the material of which they consist allows no preliminary warning of failure, those who are using them may be in positions of some danger.

The receipt of particulars of six such failures seems sufficient reason for enquiring into the nature of the stresses to which such dies may be subjected during use. Such an enquiry, moreover, raises further points of interest concerning the plastic strain in the material forming the tube. With regard to the stresses in the die it is evident that there may be initial stresses set up during its manufacture; on these will be superposed the statical stresses due to the drawing of the tube, and, further, there may be dynamical stresses caused by vibrations in the die. Any die designed to resist the statical stresses should have a large factor of safety to cover any initial and vibratory stresses which may occur, otherwise, on two or three occurring simultaneously, fracture may result.

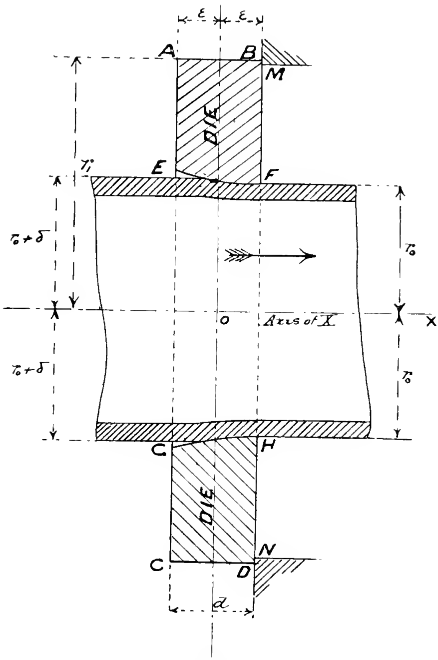


FIG. I.

The dies, one of which is shewn in section in *Fig.* 1, are sections of a right cylinder cut off by parallel plane faces perpendicular to the axis, and having an axial circular aperture passing from one face to the other and diminishing in radius at the same time. The aperture is shown at *EFGH*, the tangents to the curves at *F* and *H* being parallel to *OX*. The initial diameter of the aperture is usually greater than that of the tube, whilst the final diameters of tube and aperture are the same.

Assuming that such a die is supported by a ring *MN*, infinitely near the outer edge of the die, it can be seen that the pull of the tube would produce both bursting and bending effects. The hoop tension at the inner back edge will be due to the bursting pressure of the tube together with the tension due to bending.

The maximum stress due to these forces is shown in the following pages to be approximately—

$$(1) \qquad t = \frac{T}{4\pi d^2}\left(4 \cdot 5 + 15 \frac{r_1^2 \text{hyp. log} \frac{r_1}{r_0}}{r_1^2 - r_0^2}\right)$$

where T = total pull on tube in tons,

" d = thickness of die,

" r_0 = minimum radius of hole,

" r_1 = radius of outer edge of die.

This stress is a tension perpendicular to a radial plane, and occurs at that edge of the die where the tube leaves. [It is independent of the slope of the hole under the given assumption.]

Formula (1) is an approximation, inasmuch as it depends upon the following:—

(*a*) Assuming that there is no internal traction parallel to the axis of the die, *i.e.*, to the direction of motion of the tube, a solution of the equations of internal equilibrium for an elastic solid can be found without difficulty.

This assumption with regard to the internal traction is made by Saint-Venant when considering thick circular plates and the flexure of beams. It is probably most questionable at the curved inner face where the tube is in contact with the die, but the inclination here is slight, and its effect should rapidly vanish as the distance outwards increases.

(*b*) The solution should satisfy the external conditions. At the outside rim there should be no radial pressure or

moment. The above solution substitutes for these conditions no total radial pressure and no total moment of radial pressure on any strip of rim parallel to the axis. The surface of zero pressure is therefore sometimes slightly without and sometimes slightly within the rim.

At the inner face the manner of the distribution of the pressure between the tube and the die is unknown, but it may reasonably be taken that the pressure at the emission edge is zero, since the hole is cylindrical at that edge.

It is, therefore, necessary to assume that the total radial pressure over the inner face is proportional to the pull on the tube, the average slope of the face, and the friction between the tube and the die. The law of variation of pressure over the inner face between the die and tube, as given by these assumptions, seems sufficiently reasonable to justify their adoption.

If f_t = safe stress in the material of the die, and the ratio of external to internal radii be taken as 2, formula (1) gives

$$(2) \qquad d = \sqrt{1{\cdot}4618 \frac{T}{f_t}}.$$

By recasting the dimensions of the dies in this way, it was found that in some cases the strength could have been increased, and the weight of metal reduced at the same time.

Determination of T.

The value of T may be taken as the maximum pull which the machine is capable of exerting, or it may be obtained as follows:—Imagine the tube solid and its ends firmly gripped and then pulled apart. The force necessary to produce the required reduction of area would be

$$(3) \qquad T = 37{\cdot}91 (A_0 - A_1)^{\frac{1}{2}} A_1^{\frac{1}{4}}*$$

* *Manch. Memoirs*, Vol. 43, No. 10.

where A_0 = initial area and A_1 the final area in square inches. The author has tested copper tubes, and finds that they follow the same law.

T calculated in this way gives the maximum load which can be put on the tube without drawing it after leaving the die. Actually, however, the material is set by a tension accompanied by two pressures at right angles to it. Hence T may be reduced somewhat in the ratio 8 to 10.* But the friction between the die and tube must now be added, with the result that the total reduction cannot be large, and, should the tube stick at all, the full pull T might act on the die.

Hence it would appear safer to take the full value of T from (3).

But practical considerations prevent the ring method of support from being adopted, since the support must be made adjustable to enable dies of different sizes to be used in the same machine without waste of time whilst interchanging. Hence, the dies are supported on two parallel bars, their distance apart being adjusted by screws. If the deflection of these bars is neglected, the dies are supported on two parallel knife edges. The distance between these knife edges is usually set about 4 inches greater than the diameter of the issuing tube, but, as this depends entirely upon the judgment of the workman in charge of the machine, there is no certainty that this is a hard and fast rule. In this case, therefore, it is useless to do more than approximate to the stresses by treating the die as a thick cylinder and a beam supported on two parallel edges, and having a load applied uniformly and arranged in the form of a ring.

Thus, neglecting complications introduced by the curved form of the die, the displacement of the neutral

*An approximate determination of this ratio is given in III.

TABLE I.

Shewing the dimensions and calculated stresses in six dies which failed whilst in use.

		I.	II.	III.	IV.	V.	VI.
DIE	Number of die	I.	II.	III.	IV.	V.	VI.
	External diameter in inches $= 2r_1$	26·25	22·0	22·5	27·0	19·0	17·0
	Least internal diameter in inches $= 2r_o$	11·75	9·125	8·125	13·5	6·75	4·5
	Thickness of die $= d = 2\epsilon$	4·5	3·75	4·25	4·5	4·0	3·5
	Thickness in contact with the tube $= 2\epsilon'$	2·5	2·625	2·312	3·0	2·375	2·25
	Ratio $\frac{r_1}{r_o} = h$	2·23	2·41	2·77	2·00	2·81	3·78
TUBE	Initial external diameter of tube in inches	12·5	9·56	8·56	14·187	7·625	5·187
	Initial thickness of tube in inches	$1\frac{3}{8}$	$\frac{21}{32}$	$1\frac{5}{32}$	$\frac{31}{32}$	$\frac{13}{16}$	$\frac{11}{32}$
	Final external diameter of tube in inches	11·75	9·125	8·125	13·5	6·75	4·50
	Final thickness of tube in inches	$1\frac{1}{4}$	$\frac{9}{16}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{1}{4}$
	Decrease in external radius of tube $= \delta$	·375	·219	·219	·344	·44	·344
	Pull on tube by (3) tons $= T$	**635**	**265**	**336**	**614**	**284**	**95**

STRESSES						
Stress by (4) is $t = T\left(\frac{3\left(c - \frac{2r}{\pi}\right)}{d^2(2r_1 - 2r_o - \frac{4}{5}\delta)}\right) + T\left[\frac{m}{2\pi r_o d}\frac{r_1^2 + r_o^2}{r_1^2 - r_o^2}\right]$						
i.e. (a) due to bending	·044 T	·062 T	·041 T	·050 T	·051 T	·056 T
i.e. (b) due to bursting	·019 T	·033 T	·031 T	·019 T	·030 T	·049 T
giving a total of........................	·063 T	·095 T	·072 T	·069 T	·081 T	·105 T
Stress by (1) is $t = \frac{T}{4\pi d^2}\left(4{\cdot}5 + 15\frac{r_1^2 \text{hyp} \log\frac{r_1}{r_o}}{r_1^2 - r_o^2}\right)$	·077 T	·116 T	·097 T	·071 T	·110 T	·169 T
Inserting the values of T as above there results by (4) tons per square inch	40·0	25·2	24·2	42·4	23·0	10·0
and by (1) tons per square inch	48·8	30·7	32·7	43·8	31·4	16·0
Increment of stress by (4) due to an increase of 1 inch in the distance between the supports	3·3	2·2	1·9	3·4	2·2	·9

NOTE.—Rupture stress in the cast steel is probably 45 tons per square inch.

plane, &c., &c., the maximum stress, at the inner edge of the back is

$$(4) \qquad t = T\left[\frac{3\left(c - \frac{2r_o}{\pi}\right)}{d^2(2r_1 - 2r_o - \frac{4}{5}\delta')} + \frac{m}{2\pi r_o d}\,\frac{r_1^2 + r_o^2}{r_1^2 - r_o^2}\right]$$

where $2c$ = distance between the supporting edges in inches.

" $2\epsilon = d$ = thickness of die.

" $2\epsilon'$ = the projection on ox of the length of the arc of contact of the tube and die.

" δ = decrease in external radius of the tube.

" δ' = decrease in radius of hole, and may be taken $= \delta$ in formula (4) without serious error for the six dies in question.

" f = coefficient of friction between copper and steel well oiled assumed ·3.

" $m = \dfrac{2\epsilon' - \delta f}{2\epsilon' + \delta}$. (See Section II.)

" $T\dfrac{m}{2\pi r_o d}$ = average radial pressure over inner face.

Equation (4) is so easily obtained by adding the stresses due to bending and bursting as to need no further explanation. Table I. (pp. 6, 7) gives particulars of six dies which have failed during use. The stresses are shewn by (4) and (1), first in terms of T, in order that any other value of T may be inserted if necessary, and, secondly, with the value of T given by (3). The last line gives the increment of stress due to a variation of one inch in the distance between the supporting edges. With the exception of No. 6 all the dies seem too highly strained for the irregular conditions under which they work.

That they did not fail at once seems to show that when in use they were in a condition such that a flaw or disturbance might be sufficient to cause fracture. The most obvious remedy seems to be that of thickening the

die and thus also flattening the slope of the hole, or, if the latter is objectionable, using the same slope and backing off the edges slightly at each face. At the same time weight might be saved and liability to failure reduced by decreasing the value of h. There are practical objections to the latter course, however, as the dies could not then be rebored for use with larger tubes after wear had taken place.

In Section II. there is given the method of obtaining equation (1) from the general equations, as the case of a thick plate supported in a circular ring and loaded over an inner circular aperture may have a wider application than that given above.

II. *Stress in an annular die supported at the outer edge and loaded over the inner face.*

In *Fig.* I. let the direction of motion be taken as the positive direction of x, and let r be the radial distance of any point from ox.

Let T = total pull in direction x.

d = thickness of die = 2ϵ.

2δ = reduction in diameter of tube.

$\left.\begin{array}{l} u = \text{radial displacement} \\ w = \text{axial displacement} \end{array}\right\}$ of any point xr.

p = radial pressure assumed increasing outwards.

q = longitudinal pressure increasing in direction of ox.

t = tangential pressure, normal to any radial plane.

s = shearing stress in direction ox over planes perpendicular to r.

General Equations.

The general equations of internal equilibrium, neglecting gravitational forces, became

$$(4)\qquad p - t + r\frac{dp}{dr} + r\frac{ds}{dx} = 0.$$

$$(5)\qquad r\frac{dq}{dr} + r\frac{ds}{dr} + s = 0.$$

$$(6)\qquad p = \lambda\left(\frac{du}{dr} + \frac{u}{r} + \frac{dw}{dx}\right) + 2\mu\frac{du}{dr}.$$

$$(7)\qquad t = \lambda\left(\frac{du}{dr} + \frac{u}{r} + \frac{dw}{dx}\right) + 2\mu\frac{u}{r}.$$

$$(8)\qquad q = \lambda\left(\frac{du}{dr} + \frac{u}{r} + \frac{dw}{dx}\right) + 2\mu\frac{du}{dx}.$$

$$(9)\qquad s = \mu\left(\frac{du}{dx} + \frac{dw}{dr}\right).$$

Let

$$\frac{2(\lambda + \mu)}{2\mu(3\lambda + 2\mu)} = a \qquad \frac{\lambda}{2\mu(3\lambda + 2\mu)} = b,$$

then the following values satisfy the above equations :—

$$(10)\qquad p = -\frac{2a - b}{a}A\frac{\left(\epsilon^2 x - \frac{x^3}{3}\right)}{r^2} + \frac{2a}{a - b}Ax + \frac{a + b}{a}Ax\log\frac{r}{r_1}$$
$$- \frac{a + b}{a}\frac{1}{r^2}(\beta_1 x + \beta_2) + \frac{2(a + b)}{a}(\gamma_1 x + \gamma_2).$$

$$(11)\qquad t = \frac{2a - b}{a}A\frac{\epsilon^2 x - \frac{x^3}{3}}{r^2} + \frac{2b}{a - b}Ax + \frac{a + b}{a}Ax\left(\log\frac{r}{r_1} + 1\right)$$
$$+ \frac{a + b}{a}\frac{1}{r^2}(\beta_1 x + \beta_2) + \frac{2(a + b)}{a}(\gamma_1 x + \gamma_2).$$

$$(12)\qquad s = \frac{A(\epsilon^2 - x^2)}{r}, \quad q = 0,$$

and give

$$(13)\qquad u = \frac{(a + b)(2a - b)}{a}A\frac{\epsilon^2 x - \frac{x^3}{3}}{r} + \frac{a^2 - b^2}{a}Axr\log\frac{r}{r} + (a + b)Axr$$
$$+ \frac{(a + b)^2}{a}\frac{1}{2r}(\beta_1 x + \beta_2) + \frac{a^2 - b^2}{a}2r(\gamma_1 x + \gamma_2).$$

$$(14) \quad w = -b\left(\frac{a+b}{a-b}\right)Ax^2 - A\frac{b}{a}(a+b)x^2\left(\log\frac{r}{r_1}+\frac{1}{2}\right)$$

$$-2\frac{b}{a}(a+b)(\gamma_1 x^2 + 2\gamma_2 x) + \frac{b}{a}(a+b)A\epsilon^2\log\frac{r}{r_1} - \frac{a^2-b^2}{a}A\frac{r^2}{2}\left(\log\frac{r}{r_1}-\frac{1}{2}\right)$$

$$-(a+b)\frac{A}{2}r^2 - \frac{(a+b)^2}{a}\beta_1\log\frac{r}{r_1} - \frac{2(a^2-b^2)}{a}\gamma_1\frac{r^2}{2} - bD.$$

A, D, β_1, β_2, γ_1, γ_2, being determined by the external conditions.

External Conditions.

(I.) There must be no shearing force or axial stress over either plane face, *i.e.*, s and q must both be zero at $x = \pm\epsilon$. this is satisfied by (12).

(II.) At the cylindrical face $r = r_1$ it was found impossible to make p vanish independently of x. The course adopted, therefore, was to make

(i.) $\int_{-\epsilon}^{+\epsilon} p\,dx = 0$, *i.e.*, total radial pressure vanishes.

(ii.) $\int_{-\epsilon}^{+\epsilon} px\,dx = 0$, *i.e.*, total moment equal zero.

The value of p at the outer edge therefore varies from positive to negative, is always small, and has no resultant force or moment over the section by this assumption.

III. At the inner face

(i.) $p = o$ when $r = o$ $x = \epsilon$-

(ii.) $\int_{-\epsilon}^{+\epsilon} p\,dx = \frac{m}{2\pi r_o}T$,

m being a factor depending on the slope of the inner surface. Assuming the inner face conical, then with the previous definition of ϵ' and f

$$m = \frac{2\epsilon' - \delta f}{\delta + 2\epsilon f} \text{ approximately.}$$

If the tube is in contact with the whole of the inner face $\epsilon' = \epsilon$. By equating the total shearing stress over any cylindrical section to T there results

$$A = \frac{3T}{8\pi\epsilon},$$

whilst from II. and III.

$$\beta_2 = -\frac{mT\mu a}{4\pi r_o \epsilon} \frac{2r_1^2 r_o^2}{r_1^2 - r_o^2},$$

$$\gamma_2 = -\frac{mT\mu a}{4\pi r_o \epsilon} \frac{r_o^2}{r_1^2 - r_o^2},$$

$$\beta_1 = \frac{-\frac{2a-b}{a} A\epsilon^2\left(\frac{4}{5}\frac{1}{r_1^2} - \frac{2}{3}\frac{1}{r_o^2}\right) + A\frac{a+b}{a}\log\frac{r_1}{r_o} + \frac{a+b}{a}\frac{1}{r_o^2}\frac{\beta_2}{\epsilon} - \frac{a+b}{a}\frac{2\gamma_2}{\epsilon}}{\frac{a+b}{a}\left(\frac{1}{r_1^2} - \frac{1}{r_o^2}\right)}$$

$$\gamma_1 = \frac{\beta_1}{2r_1^2} - \frac{16}{15}A + \frac{14}{25}A\frac{\epsilon^2}{r_1^2}.$$

As the result of several experimental determinations of E and μ for cast steel, given in Unwin's *Strength of Materials*, it may be taken that $E = \frac{5}{2}\mu$. This is equivalent to making $\lambda = \mu$ or $b = \frac{a}{4}$.

Therefore, putting

$$\frac{r_1}{r_o} = h, \quad \frac{\epsilon}{r_o} = l,$$

$$\beta_2 = -\frac{mT}{5\pi l}\frac{h^2}{h^2 - 1}, \quad \gamma_2 = -\frac{mT}{10\pi l r_o^2}\frac{1}{h^2 - 1},$$

$$\beta_1 = \frac{T}{200\pi l r_o (h^2 - 1)}\left(84 - 70h^2 - 75\frac{h^2}{l^2}\log h + 40m\frac{h^2}{l}\right),$$

$$\gamma_1 = \frac{T}{400\pi l^3 h^2 (h^2 - 1) r_o^3}\left[40mlh^2 - 75h^2\log h - 160lh^2(h^2 - 1)\right],$$

and

$$t = \frac{T}{\pi r_o^2}\left[\frac{7}{16} - \frac{9}{32l^2} - \frac{15}{16}\frac{h^2\log h}{(h^2 - 1)l^2} + \frac{98}{160(h^2 - 1)} - \frac{7}{16}\frac{h^2}{h^2 - 1}\right],$$

which is approximately, for the values obtaining in practice,

$$t = -\frac{T}{4\pi d^2}\left(4{\cdot}5 + 15\frac{h^2\log h}{h^2 - 1}\right).$$

The value of the radial pressure over the inner face will not differ greatly from that obtained by treating r as constant and equal to r_o, then

$$p = -\frac{1}{3}\,\frac{2a-b}{a}\,A\,\frac{(\epsilon^2 - x^2)x}{r_o^2} + \frac{mT}{4\pi r\epsilon}\left(\frac{\epsilon - x}{\epsilon}\right)$$

one root is $x=\epsilon$. In order that there shall be no root between $x=+\epsilon$ and $x=-\epsilon$, we must have

$$m > \frac{7\epsilon}{4r_o} < 0$$

i.e.,

$$f < \frac{8\epsilon' r_o - 7\epsilon\bar{c}}{14\epsilon\epsilon' + 4\bar{c}r_o} \text{ or } > \frac{2\epsilon'}{\bar{c}}.$$

For the 6 cases given, in which f is assumed $=\cdot3$, f must be

	I.	II.	III.	IV.	V.	VI.
less than	·92	1·18	·90	2·00	1·27	·54
or greater than	6·66	12·00.	10·5	9·00	5·4	6·5

a condition which for the usual values of f would be fulfilled.

Thus the form of the pressure curve over the inner face will be somewhat as shewn in *Fig.* II., and seems in agreement with the most natural suppositions.

The constant term in the expression for t is

$$\frac{a+b}{a}\,\frac{1}{r^2}\beta_2 - \frac{2(a+b)}{a}\gamma_2$$

i.e.,

$$\frac{-mT}{4\pi r_o\epsilon}\;\frac{r_1^2 + r_o^2}{r_1^2 - r_o^2}$$

and since the total outward radial pressure over an axial strip of inner face is $\dfrac{m}{2\pi r_o T}$, the above becomes

$$-p'\frac{r_1^2 + r_o^2}{r_1^2 - r_o^2}$$

where p' is the average radial pressure over the face considering the die as a thick cylinder, and resolving T radially according to the slope of the hole.

The following example has been worked out completely

$$r_0 = 6{\cdot}75'' \quad r_1 = 13{\cdot}5'' \quad \epsilon = 1{\cdot}5'' = \epsilon' \delta = {\cdot}344''$$

$$T = 605 \text{ tons } h = 2 \; l = \frac{2}{9} \; f = {\cdot}3$$

then at $r = r_1$

$$p = {\cdot}0685x^3 - {\cdot}094x,$$

at $r = r_0$

$$p = {\cdot}274x^3 - 8{\cdot}0x + 11{\cdot}073,$$

at $r = r_0$

$$t = -{\cdot}274x^3 - 52{\cdot}33x - 18{\cdot}455.$$

$$r = r_1$$

$$t = -{\cdot}069x^3 - 22{\cdot}29x - 7{\cdot}382,$$

Figs. II. and III. shew these stress curves, drawn to scale.

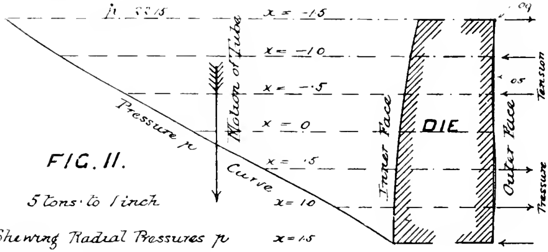


FIG. II.

5 tons to 1 inch

Shewing Radial Pressures p over inner and outer faces to same scale Section of opposite half of die omitted

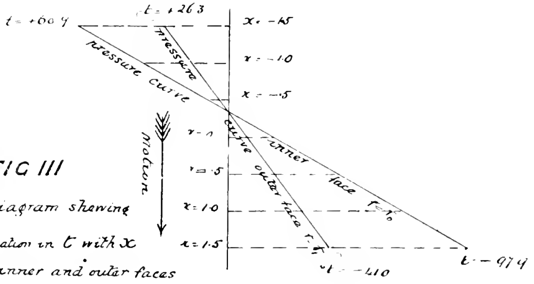


FIG III

Diagram shewing variation in t with x at inner and outer faces

Again at

$r = r_0$

$$u = -\frac{1}{E}(2 \cdot 31x^3 + 272 \cdot 4x + 80 \cdot 97)$$

at $r = r_1$

$$u = -\frac{1}{E}(1 \cdot 16x^3 + 279 \cdot 3x + 68 \cdot 5),$$

and when

$$x = \epsilon \quad r = r_0 \quad w = -\frac{2283}{E}$$

$$x = \epsilon \quad r = r_1 \quad w = 0$$

$$x = -\epsilon \quad r = r_0 \quad w = -\frac{2289}{E}$$

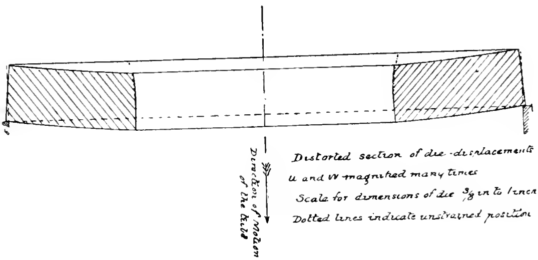
$$x = -\epsilon \quad r = r_1 \quad w = -\frac{5 \cdot 5}{E}$$

$$x = 0 \quad r = r_0 \quad w = -\frac{2306}{E}$$

$$x = 0 \quad r = r_1 \quad w = -\frac{2}{E}$$

the distorted section of the die is shewn in *Fig.* IV., in which the displacements u and w are plotted to a larger scale than that to which the die is drawn.

FIG. IV.



III. *Assistance in extending the tube rendered by lateral pressure.*

Take longitudinal axis, radius and tangent as axes for a unit cube.

Let the forces be three pairs of normal pressures p_x, p_r, p_t.

Let a_x, a_r, a_t be the strains in the cube, and let e_x, e_r, e_t be those parts of a_x, a_r, a_t due to p_x, p_r, p_t alone,

Then

$$a_x = (e_x - me_r - me_t).$$
$$a_r = (-me_x + e_r - me_t).$$
$$a_t = (-me_x - me_r + e_t).$$

where m is the ratio of lateral to longitudinal extension.

Since $a_r = a_t$ for the tube, it is easily seen that $p_r = p_t$ as long as the relations between the stresses and strains are the same. Now for deformation up to maximum load

$$p = Ce^n,$$

or $e = Ap^k$ and since there is little or no change in density

$$a_x + 2a_r = 0,$$

which gives

$$p_x^k + 2p_r^k = 0,$$

or

$$p_x = \frac{Ca^n}{(1+m)^n}$$

For tension alone a stress of p'_x would be required $= Ca^n$; hence, the ratio of these is

$$\frac{p_x}{p'_x} = \frac{1}{(1+m)^n}$$

within the elastic limit $n = 1$ is m usually taken $\frac{1}{4}$.

In copper after yield point $n = \frac{1}{2}$ nearly, whilst careful density measurements make it reasonable to assume m constant up to maximum load, and equal to the value given by the the extension at this point, *viz.*, ·604.

The ratio then becomes $\sqrt[2]{\frac{1}{1\cdot604}}$ or ·8.

Thus under the best conditions a reduction of 20 per cent. of the pull might occur, but it is probable that friction would largely counterbalance this, as it would then have to be taken into account.

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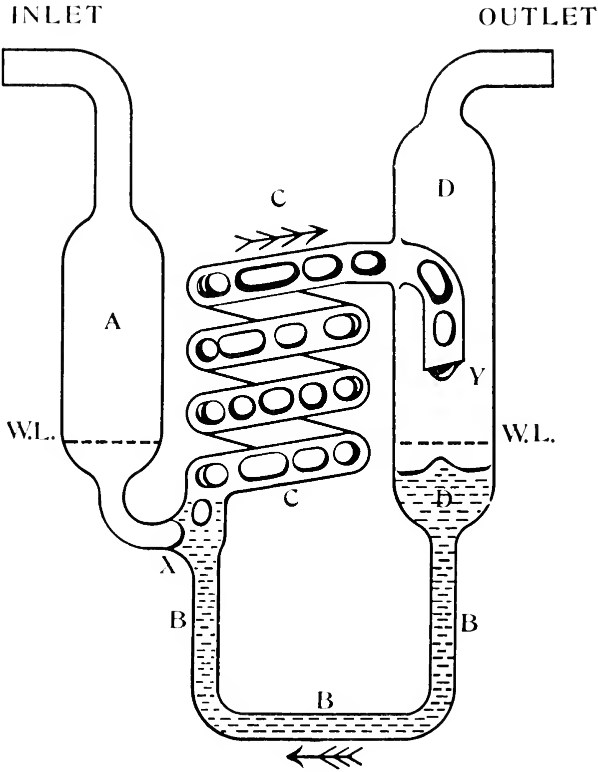
VIII. Chemical Gas Washing Apparatus.

By C. E. Stromeyer, M.Inst. C.E.

Received and read January 7th, 1902.

In connection with some boiler trials which will shortly have to be carried out, it was desirable to devise a gas absorption apparatus containing as small a quantity as possible of absorbing fluid, and capable of dealing with large volumes of gas, conditions which are not infrequently met with in chemical laboratories. The various types of potash bulbs, used by chemists, were found to be unsuitable, more especially as the time during which the gas remains in contact with the absorbing fluid is not much greater than the time taken by each bubble to pass upwards through about one inch of fluid. Not being able on account of the growing pressure to increase the depth of fluid, I devised the apparatus shewn in the figure, in which the gas, after passing through A, breaks into bubbles at the point X, where it first comes in contact with the absorbing fluid which circulates in BB, as indicated. The bubbles which are formed at X are constrained to travel through several inches of coiled glass tubing CC, so that the time of contact does not now depend on the depth of fluid but on the volume of gas passed through the apparatus per second. On entering the vessel DD the bubbles burst, the gas escaping upwards, the fluid returning to the pipe BB and circulating back to the point X.

February 10th, 1902.



Although with a reasonable height of fluid in DD circulation through CC is possible, even if BB is level with X, yet in practice it was found that at the start of an operation the gas would prefer the shorter path; for this reason, BB had to be made in the shape of a loop about three or four inches deep.

The pressure required for driving the gas through this apparatus is represented by the difference of height between the working level in DD and X; this is equal to the resistance in the coil added to the difference of level between X and Y, allowance being made for the large percentage of air bubbles in the coil and downtake Y.

The internal diameter of the coiled tube should be about $\frac{1}{8}$ inch; if made smaller, the capacity of the apparatus is much reduced and the resistance increased. If the diameter is made larger than one quarter inch, bubbles are not formed, the fluid is not carried over into DD, and the apparatus is then, in fact, reduced to a Winkler worm of inefficient design. The essential principle of my apparatus is that the fluid must be carried over with the gas.

Of the several models shewn, one of the more satisfactory ones had a coil 30 inches long and $\frac{1}{8}$ inch internal diameter, with a difference of level between X and Y of $1\frac{1}{4}$ inch. A stream of air was completely broken up into bubbles even when as much as seven litres of air were passed through per hour. Under these conditions the estimated duration of contact of bubbles and fluid was $2\frac{1}{2}$ seconds.

A larger model, having a coil four feet long and $\frac{1}{4}$ inch bore, worked best when about 50 litres per hour were passed through it, contact lasting for about 3 seconds. A much larger volume of air, driven by laboratory bellows and charged with hydrochloric vapour, has been passed through this apparatus, the absorption being complete as shewn by the nitrate of silver test, even although the bubbles were very large and the absorbing fluid was very weak.

Manchester Memoirs, Vol. xlvi. (1902), *No.* 9.

IX. On Xenophyton radiculosum (Hick), and on a Stigmarian Rootlet probably related to Lepidophloios fuliginosus (Williamson).

By F. E. Weiss, B.Sc., F.L.S.,
Professor of Botany, Owens College, Manchester.

Received and read January 21st, 1902.

I. *Xenophyton radiculosum* (Hick).

In a paper read before the Linnean Society of London, in 1891, my late colleague, Mr. Thomas Hick, described a new fossil plant, found by W. Cash, Esq., at the Cinder Hills, Siddal, near Halifax, to which he gave the provisional name of *Tylophora radiculosa*, afterwards altered to *Xenophyton radiculosum.* Hick felt in some doubt as to its systematic position, but Professor Williamson, to whom he showed the specimen, was of the opinion that its affinities were with *Stigmaria*, of which he considered it might be a new type. This view was, however, not adopted by Hick on account of certain differences which the specimens presented when compared with the well known stigmarian types, and he preferred to leave its relationship an open question. This uncertainty as to its nature, and the fact that no further specimens of this plant have been discovered, are probably the reasons why it has received so little attention. A number of transverse and longitudinal sections of this fossil, prepared by Mr. James Lomax, and representing the material investigated by Hick, came into the possession of the Manchester Museum by the purchase of the Hick and Cash Collections

March 10th, 1902.

of Coal Measure Plants. They are Nos. 148-162 of the Cash Collection and No. 171 in the Hick Collection.

A careful examination of these slides leads me to support the view expressed by Williamson that the plant was of stigmarian character, and certain features revealed by the preparations warrant, I think, a further identification of this *Stigmaria* as the "root" or rhizome of a *Lepidophloios*, probably of *Lepidophloios fuliginosus*.

The external view of the specimen, with its quincuncial arrangement of rootlets, as shown in *Fig.* 1 of Hick's paper, is very suggestive of a *Stigmaria*, and, though the transverse section is at first sight different from that of the more common forms of *Stigmaria*, yet on a closer examination it will be found that the differences are differences of proportion rather than of kind.

Hick's *Fig.* 2 was based partly upon a photograph and partly on a diagrammatic drawing. *Fig.* 1 of the present paper is a photograph by Mr. Abraham Flatters, from another transverse section, which will be seen to be very like that figured by Hick. It differs chiefly in the splitting open of the vascular cylinder by the intrusion of one of those ubiquitous stigmarian rootlets, which is also visible by the side of the vascular cylinder in Hick's drawing.

Besides the central stele, *Fig.* 1 shows very clearly the general character of the middle cortex ("radicular tissues" of Hick), with its curious marking, the outer cortex with its large and clearly defined cells, and the periderm lying imbedded in the outer cortex.

1. *The pith.*

The presence of a well-defined pith, described and figured by Hick, is the first character of some difference from the usual specimens of *Stigmaria*. The numerous specimens examined by Williamson ('87) were all hollow

at the centre, so that he arrived at the conclusion that *Stigmaria* possessed a "fistular medulla," though he often found thin layers of pith cells lining the vascular cylinder and in continuity with the primary medullary rays. Scott,* too, speaks of the pith being rarely preserved, except in the outer part, and possibly of a fistular nature. The presence in *Xenophyton* of such a well-defined medullary tissue might be due (*a*) to the age of the specimen, (*b*) to the state of preservation, or (*c*) to a specific difference between *Xenophyton* and other *Stigmariæ*.

(*a*) It might be argued from the persistence of the pith that our *Xenophyton* specimen was a young *Stigmaria*, in which the fistular character of the pith had not yet been developed. But the size of the specimen is greater than that of many *Stigmariæ*, which have a hollow pith, so that we have no reason, from its size, of supposing it to be a young "root." The small amount of secondary wood might possibly be taken as indicative of its youthful condition, but I am inclined to look upon this as a specific difference of this specimen. The presence of a well-marked periderm, as well as the bulk of the specimen, incline me to the belief that we have to do with a mature specimen.

(*b*) As regards the state of preservation of the specimen, the presence of an extraneous stigmarian rootlet outside the central vascular cylinder, and even burrowing into the pith (as in the section figured in the present paper), indicate that the specimen must have been exposed to some destructive changes before fossilisation, so that the preservation of the pith in our specimen would point to a considerable durability of this tissue.

(*c*) As in the specimen before us, then, we have the pith well preserved in what we must regard as a mature

* Scott, D. H. ('00) p. 222.

specimen, while in most *Stigmariæ* we find this tissue very defective, it follows that we must consider the pith in this *Stigmaria* as of greater strength and persistence than is usually the case.

2. *The stele.*

The central vascular cylinder is of the normal stigmarian type, as seen from Hick's description and figures. *Fig.* 2 of the present paper also shows this typical stigmarian arrangement of the tracheids. There is no clear demarcation between primary and secondary wood, but a gradual transition from the smaller tracheids near the centre to the larger ones near the periphery. Smaller rows of tracheids seem to force themselves in a somewhat irregular manner between the larger ones. The whole arrangement points clearly to a purely centrifugal development of the wood which is so characteristic of *Stigmaria.* The wood is interrupted by larger primary medullary rays, opposite which the vascular supply to the rootlets is given off.

The origin of the vascular supply to the rootlets can be made out in one of the tangential longitudinal sections, and has the appearance typical of *Stigmaria*,* though not in so striking a manner as is usual in that fossil, owing to the small amount of secondary thickening.

Outside the secondary wood there are rows of smaller thin-walled cells, which, by their shape and regular arrangement, indicate that they are of a secondary nature, and they probably include the generative layer, or cambium, though it is impossible to distinguish the actual meristematic layer.

Beyond this secondary tissue we find a small-celled primary tissue, which must be taken to be equivalent to the phloem of recent plants. The cells are often filled

* *cp.* Williamson ('87) *Plate* V., *Figs.* 8 and 16.

with a dense black mass, rendering portions of the tissue quite opaque. Where the cells are visible, they are small and arranged sometimes in fairly regular radial rows, sometimes in groups, not unlike those I have described for the phloem of *Lepidophloios* and *Lepidodendron*.

A lacunar zone is not developed, though in one or two places lacunæ appear in process of formation in the phloem region, and, as I have pointed out elsewhere,* the lacunar tissue probably represents only a defectively preserved phloem region.

The phloem is, like the xylem, definitely interrupted by broad primary medullary rays consisting of parenchymatous cells exhibiting some radial elongation.

No definite pericycle can be distinguished, though it is possible that one or more of the layers of cells designated as the inner cortex may have partaken of the nature of a pericycle.

3 *The cortical tissues.*

The cortical tissues are much better preserved in *Xenophyton* than is usually the case in *Stigmaria*, and it is to the almost perfect preservation of its middle cortex that a transverse section of *Xenophyton* owes its characteristic appearance. As in the stem of the *Lepidodendreæ*, one can distinguish in *Xenophyton* an inner cortex (the "problematical pericycle" of Hick), the middle cortex ("radicular tissues" of Hick), and the outer cortex ("true cortex" of Hick).

The inner cortex forms a sheath of more or less closely-set cells, five or six layers in thickness, around the stele. The cells seen in transverse section (*Plate* XI., *Fig.* 2) are smaller in diameter than the cells of the middle cortex. They are elongated in the direction of the long axis of the *Stigmaria*, and fitted together by

* Weiss, F. E. ('01).

oblique walls when seen in longitudinal section (*Plate* XII., *Fig.* 1). In such sections, the demarcation between the inner cortex and the middle cortex is more distinct than in transverse sections. The middle cortex, which is as rarely preserved in *Stigmaria* as in lepidodendroid stems, is conspicuous in *Xenophyton*, both by its massiveness and by the excellence of its preservation. Hick regarded this middle cortex, or "radicular tissue" as he called it, as intercalated by secondary development between the outer and inner cortex. But though we have evidence that certain secondary changes take place within the middle cortex, there is not, I think, sufficient evidence to regard it as due entirely to secondary growth. On the contrary, it corresponds closely with the middle cortex of the stem of the *Lepidodendreæ* which, except in *Lepidophloios fuliginosus*, is so rarely preserved. It also corresponds in position with the lacuna left by the defective tissue in *Stigmaria* between the central cylinder and the outer cortex, and with the similar space left in the stigmarian rootlets by the defective middle cortex.

The irregular and patchy appearance of this tissue in *Xenophyton* is due to the passage through it of the vascular bundles which are to supply the rootlets, and it is around these bundles more particularly that secondary changes in the cortex seem to take place. Otherwise, the middle cortex seems composed of short polygonal or square cells, with a certain amount of intercellular space sometimes showing that growth characteristic of this layer in the *Lepidodendreæ* (more particularly in *Lepidophloios*) where it often appears made up of interwoven filaments, like a sclerotial tissue of a fungus (*Plate* XI., *Fig.* 3).

In some places the middle cortex seems to possess definite powers of secondary growth, and its cells often show a radiating arrangement around the rootlet bundles.

In connection with these bundles, and also in other parts of the middle cortex (more particularly near its outer limits, as can be seen in *Fig.* 1), one encounters dark wavy lines, which seem to be due, in some cases, to the compression of cells along certain lines, but in other cases have the appearance of an infiltration of some substance into the intercellular spaces. They are often accompanied by definite bands of flattened cells of a secondary nature.

The outer cortex, or what Hick called the "true cortex," consists of larger and thick-walled cells, fitting more closely together than the cells of the middle cortex, and showing a more regular arrangement. Near the outside of this cortical layer a band of periderm is visible, the cells of which do not, however, show any considerable broadening towards the outside, as is often the case in *Stigmaria*. The amount of periderm differs very much in different parts of the circumference, sinking in one place to only four layers of cells. In these thinner parts it seems possible to recognise the innermost layer as the phellogen, but in other regions it is impossible to discover which is the generative layer.

Close below the periderm there are distinct groups of secreting tissue in the outer cortex, like those which have been described by Seward for *Lepidophloios fuliginosus*,* and for *Lepidophloios Harcourtii*,† and exactly similar to those I have myself seen in the former species.

4. *The rootlets.*

The external appearance of *Xenophyton* showed unmistakable traces of rootlets, with a similar arrangement to those of *Stigmaria*.

In transverse sections, the vascular supply to these

* Seward, A. C. ('00).

† Seward, A. C. and Hill, A. W. ('00).

rootlets will be seen to be given off in a manner equally typical of *Stigmaria* (*Plate* XI., *Fig.* 2), leaving broad medullary rays opposite the outgrowing bundle, which represents a complete segment of the vascular elements of the stele with the protoxylem on the inner face. As is seen from the longitudinal section, the bundle is given off very obliquely at first. As there is very little secondary growth in the stele, we do not find that horizontal connecting piece running in the medullary ray, which must necessarily be formed as the secondary tissues increase in thickness.

The vascular branch carries with it a portion of the phloem on the outside, just as do the leaf-trace bundles in the stems of the *Lepidodendreæ*, and each may be considered as monarch if we adopt the usual terminology of roots. In passing outwards, the vascular supply to the roots will be seen to be enveloped by a sheath of cells, in direct continuity with the inner cortex (*Plate* XI., *Fig.* 2, and *Plate* XII., *Fig.* 1).

A great amount of meristematic activity seems to take place in tissues of the middle cortex, especially on the inside of the bundle running to the rootlet. Here, by division of the cortical cells, a little cushion of smaller cells is formed, often showing clearly their secondary origin, as in Hick's *Fig.* 6. Sometimes the tissues are, however, less regularly arranged, as in *Plate* XII., *Fig.* 2, of the present paper, where the secondary cells on the inside of the rootlet are clearly distinguishable from the primary cortex of the *Stigmaria* by their smaller size and by the distinct line of demarcation due to a compression of the adjoining cells.

As the rootlet-bundle passes further outwards, it comes to lie more centrally, and ultimately completely, in the middle of this proliferation of the middle cortex,

which often forms a star-shaped mass of cells around it, indicating by its very regular rows of cells its secondary origin (*Plate* XII., *Fig.* 3).

On nearing the periphery, too, the rootlet will be found to be surrounded by a sheath of cells corresponding in structure with the outer cortex and directly connected with it (*Plate* XII., *Fig.* 4). These intruding bands of cortex, which form an outer sheath to the rootlet, are seen in transverse section (*Plate* XI., *Fig.* 1).

The rootlet-bundle is only slightly inclined to the long axis while passing through the middle cortex, so that the rootlet-bundles are cut very nearly transversely in a transverse section. This steep course is adhered to even in the outer cortex, until the cushion of the rootlet is reached. Thus, in *Plate* XII., *Fig.* 4, the vascular branch is seen cut slightly obliquely just beneath the cushion.

While passing through the cushion or diaphragm, however, and also beyond it, the bundle of the rootlet is at right angles to the long axis of the *Stigmaria*. The structure of the cushion is essentially the same as that in *Stigmaria* as described by Williamson, Solms, and Scott. It consists of closely-set cells of smaller size, and is supposed to be formed from the outer cortex. What connection, if any, it has with the middle cortex, remains still to be determined.

Beyond this close-celled diaphragm, the rootlet shows distinctly the three layers of cortical cells typical of a stigmarian rootlet, and tangential sections show figures of the emerging rootlets, similar in all respects to those figured by Williamson.*

General Conclusions.

From the foregoing description of *Xenophyton*, it will

* Williamson ('87) *Plate* IX., *Fig.* 51.

be seen that I support strongly Williamson's opinion of the stigmarian nature of *Xenophyton radiculosum*, and, briefly, on the following grounds:—

(1) The general appearance of the fossil, with quincuncially arranged rootlets.

(2) The character of the stele, with its centrifugal xylem and broad medullary rays corresponding with rootlet-bundles.

(3) The organisation of the monarch rootlets differing in no particular from stigmarian rootlets.

(4) The structure of the rootlet-cushion.

Some of the differences of *Xenophyton* from the ordinary *Stigmariæ* will, I think, on second consideration, be found to present no difficulties in the way of this identification.

In connection with the presence of a well-preserved pith, I have already pointed out that this cannot be considered as more than a specific difference at most.

A more pronounced characteristic of *Xenophyton* is the small development of secondary wood. If this character was shared by the stem with which *Xenophyton* was connected, a not unwarrantable assumption, it would point to an association of *Xenophyton* with a stem such as that of *Lepidophloios*, in which genus we have a similar reduction, or at all events retardation, in the formation of secondary wood.

A more typical feature still is the massiveness of the middle cortex of *Xenophyton* and its excellent preservation. In no known member of the *Sigillariæ* or *Lepidodendreæ* do we find anything so nearly resembling this development as in *Lepidophloios fuliginosus*, in which we have both a massive middle cortex and also one which is generally exceedingly well-preserved. The character of its cells, too, though varying slightly in different

specimens of *Lepidophloios fuliginosus*, is very like that of *Xenophyton* described above. Indeed, *Fig.* 1 of *Plate* XII. of the present paper might have been taken from the middle cortex of *Lepidophloios fuliginosus*. Taking these circumstances into consideration, I have little hesitation myself in connecting these two fossil plants together and in considering *Xenophyton* as the "root" of *Lepidophloios fuliginosus*.

Other points in the anatomy of these two forms, such as the secretory tissue lying beneath the periderm, strengthen this identification.

II. A STIGMARIAN ROOTLET PROBABLY RELATED TO *Lepidophloios fuliginosus*.

A stigmarian rootlet probably closely connected with the above described *Xenophyton*, and therefore most likely with *Lepidophloios fuliginosus*, is contained in the Hick Collection of Coal Measure Plants in the Manchester Museum. Its Cabinet number is 109. Unfortunately, I can find no locality given for this specimen, but from the appearance of the surrounding mass of *débris* it was evidently enclosed in one of the "coal balls," from which so many interesting specimens have been obtained. The rootlet has a diameter of five to six millimetres, so that it will be seen to be of a fairly large size. It is almost spherical in section, showing little or no lateral compression, a fact which is doubtless in some measure due to the firmness of its tissues, which are all very perfectly preserved (*Plate* XIII., *Fig.* 1). The outer cortex is not of great thickness, being composed of only four or five layers of cells, of which the outermost row consists of cells of much smaller size than the inner cells. In no place is there any appearance of rhizoid-like prolongations of the epidermal cells, nor are any other projecting lateral

organs visible. In some places the outer cortex is only two or three cells in thickness, and at some points only one layer of cells is visible, but here it would appear that the outer layers have become destroyed, probably after the death of the root.

The middle cortex, which is so generally absent or defective in stigmarian rootlets, is, in the specimen under consideration, represented by a massive and well-preserved tissue of the character usually found in *Lepidophloios fuliginosus*, and also seen in *Xenophyton.* The more or less elongated cells (*Plate* XIII., *Fig.* 4) form a dense felted mass, evidently of greater strength than is usual in the middle cortex of stigmarian rootlets, if, indeed, the latter possessed in all cases a definite middle cortex. It is quite conceivable that in many stigmarian rootlets there may have been a definite space between the outer and inner cortex, bridged over only at one side by a strand of cells such as we find in the roots of *Isoëtes.* Such roots are figured by Williamson.* On the other hand, some rootlets with well-preserved middle cortex have been figured by Williamson,† Hooker ('48), and Goeppert ('41), but in none of these cases was the tissue of the same character as that under consideration. It seems probable that the stigmarian rootlets, representing as they do the roots of widely different plants, possessed some diversity in structure, and the presence or absence of a middle cortex, and the structure of this layer when present, would seem to have been one of the variable features of these roots. The presence and the nature of the middle cortex in the rootlet under consideration, and its excellent preservation depending, as it must largely do, upon the nature of its cells, point to a close association of this

* Williamson, W. C. ('87) *Plate* XIII., *Fig.* 79.
† Williamson, W. C. ('81) *Plate* LIII., *Fig.* 15.

rootlet with the fossil described above, *Xenophyton radiculosum*, and consequently also with *Lepidophloios fuliginosus*.

Another interesting feature of the present rootlet is the fact that this middle cortex possessed meristematic properties in its outer layers, as can be seen in *Figs.* 1 and 4 of *Plate* XIII. At all events, there are regions in which distinct growth of a secondary nature has taken place. This secondary tissue, which is not continuous around the root, seems to have been formed in a centrifugal manner. Its function must remain problematical, but was possibly of a protective character and this tissue may have been formed to replace the somewhat defective outer cortex (see *Plate* XIII., *Fig.* 1). I have also found similar patches of secondary growth in the outermost layers of the middle cortex in certain sections of the stem of *Lepidophloios fuliginosus*.

The inner cortex seems to have been of a more delicate character than the middle cortex, but, unfortunately, the central portion of the rootlet is cut somewhat obliquely, so that its tissues are not very distinct in an enlarged view. It will, however, be seen (*Plate* XIII., *Fig.* 3) that the inner cortex consisted of four or five rows of cells, set more or less closely together, very different in texture and arrangement from the cells of the middle cortex.

The stele shows the usual monarch arrangement of the conducting tissues, if we take the space on one side of the xylem to represent the position of the phloem elements. The xylem has one very distinct group of smaller elements which can be identified as protoxylem, though, as in many stigmarian rootlets, a few small tracheids are found at the opposite side of the xylem.

The protoxylem elements will be seen to project somewhat into the sheath formed by the inner cortex, as

is often the case in the rootlets.* This feature has assumed some importance on account of Renault's† statement that it is not rare to find this apex connected with a single strand of tracheids which, surrounded by a sheath, make their way through the cortex to the exterior of the rootlet. Solms Laubach,‡ in his account of the stigmarian rootlets, expresses some doubt as to the existence of such branches from the root-bundle, and he had a right to maintain this attitude of reservation, as neither he nor anyone else had "been able to find anything of the kind before or since in material from England, which has been examined over and over again," and as he was unable to recognise the tracheid as such with any certainty "in Renault's specimen." The lack of corroborative evidence, if such branches are of frequent or normal appearance, may have been due to the defective preservation of the tissue of the middle cortex in most stigmarian rootlets. Even in Renault's specimen that tissue is not entirely preserved.

In our present specimen, where this tissue is so strongly developed and so well preserved, one is able to see (*Plate* XIII., *Fig*. 3) in the middle cortex, opposite the protoxylem group, a horizontally running structure, which I take to be identical with the vascular branch described by Renault.

On a more enlarged scale (*Plate* XIII., *Fig*. 2), it will be seen to consist of a row of tracheids, clothed by a fairly distinct sheath which, however, I have not been able to trace into direct connection with the inner cortex of the rootlet.

* Williamson, W. C. ('81) *Plate* LIII., *Fig*. 19.

† Renault, M. B. "Cours de botanique fossile," première année, p. 160, deuxième année, p. 64, and *Fig*. 5, *Plate* II.

,, ,, *Annales des sciences géologiques*, 1882, *Plate* II., *Fig*. 8.

‡ Solms Laubach ('91) p. 279.

The first portion of the course of this lateral branch is at right angles to the long axis of the root, but it seems afterwards to become parallel, or nearly so, to the axis of the root, if the little star-shaped group of cells with the darker centre represents, as I take it to do, the transverse section of this peculiar strand of tracheids with its parenchymatous sheath.

I have been unable to find any similar organs running longitudinally in any other portion of the middle cortex, and if they are given off from other portions of the xylem strand, they would of course be at a different level, and might not be visible in this transverse section. Indeed, except where they run longitudinally, such delicate vascular branches, consisting of a single row of tracheids, would be excedingly difficult to recognise. It would be easier to find such tracheids in the outer cortex or on the surface of the root, if they run as far as that. But in the present specimen no further trace of them can be seen except that mentioned above and figured in *Figs.* 2 and 3 of *Plate* XIII., and it is consequently uncertain what were their course and their function in this rootlet, which differs in many particulars from that figured by Renault. From its appearance and mode of origin, I conclude that it was an organ of some importance to the rootlet, and an examination of stigmarian rootlets of the type figured by Renault confirms his statement that its occurrence is by no means rare. I hope to be able soon to complete a detailed examination of this point, but may take this opportunity of stating that the evidence I have at present does not confirm Renault's view that these vascular branches pass into secondary rootlets (radicelles), but that in some instances, at any rate, they supplied a plexus of tracheids running on the inside of the outer cortex.

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EXPLANATION OF PLATES.

PLATE XI.

Xenophyton radiculosum (Hick).

Fig. 1. Transverse section of axis somewhat enlarged. (Cash Collection, No. 150. × $2\frac{1}{2}$).

o.c. = outer cortex.

m.c. = middle cortex with irregular dark bands and rootlet-bundles (*r. b.*).

st = stele split open by a stigmarian rootlet.

Fig. 2. A portion of the stele, showing outward passage of a monarch rootlet-bundle with well-preserved phloem. This photograph shows primary and secondary xylem and the well-developed pith. The phloem elements are recognisable by the dark contents of their cells. The regular small-celled outer cortex is easily distinguishable from the darker and more loosely connected cells of the middle cortex (Cash Collection, No. 149. × 25).

Fig. 3. A portion of the middle cortex, showing the irregular course of the hypha-like rows of its cells. (Cash Collection, No. 148. × 25.)

PLATE XII.

Xenophyton radiculosum (Hick).

Fig. 1. A longitudinal section cut slightly obliquely through the stele, close to the origin of a rootlet-bundle (Cash Collection, No. 154. × 25). [This section has been inverted to facilitate the lettering.]

m = pith.
x = xylem.
ph = phloem.
i.c. = inner cortex.
m.c. = middle cortex.
r.b. = rootlet-bundle.

Fig. 2. A rootlet-bundle on its outward course through the middle cortex (Cash Collection, No. 148. × 25).

ph. = phloem.
x = xylem.
m.c. = middle cortex.
m.c.r. = middle cortex of rootlet formed by secondary growth on the outside of rootlet-bundle.

Fig. 3. A rootlet-bundle near the outside of the middle cortex, surrounded by radiating strands of cells of middle cortex. The inner cortex forms a sheath round the xylem and phloem (Cash Collection, No. 148. × 40).

Fig. 4. A rootlet-cushion with the adjoining outer cortex. At the base are seen the xylem and phloem of the rootlet-bundle cut nearly transversely (Cash Collection, No. 149. × 15).

PLATE XIII.

Stigmarian rootlet (Hick Collection, No. 109).

Fig. 1. General view of rootlet (× 8).
o.c. = the thin outer cortex.
m.c. = the massive middle cortex.
In the centre the stele surrounded by the thin-walled inner cortical cells.

Fig. 2. A much enlarged view (× 80) of the vascular branch of the stele in the middle cortex.
i.c. = inner cortex.
px. = apex of protoxylem.
tr. = tracheid strand.
sh. = sheath.

Fig. 3 View of stele, inner cortex (*i.c.*), and the adjoining portion of middle cortex (*m.c.*), showing the character of the latter and the vascular branch of the stele running into cortex (× 40).
v.b. = vascular branch.
px. = protoxylem.

Fig. 4. Outer portion of rootlet (× 40) showing—
o.c. = outer cortex.
m.c. = middle cortex, with the secondary tissue (*s.t.*) developed in its outermost layers.

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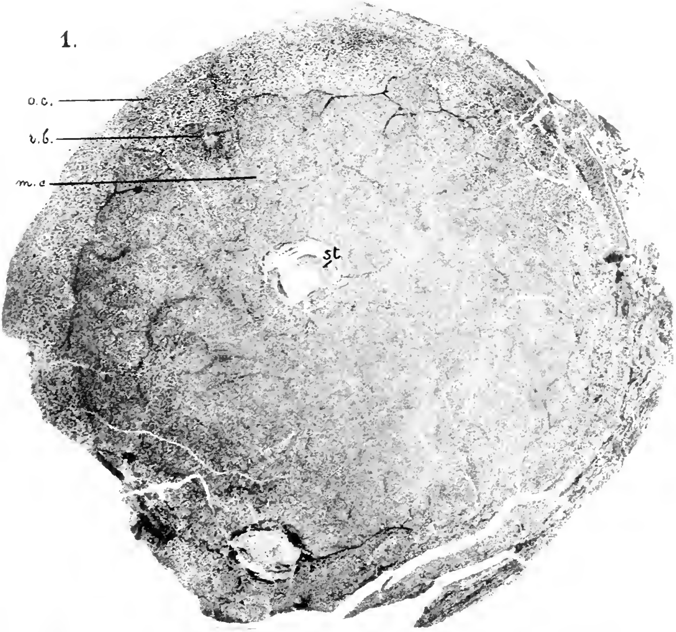

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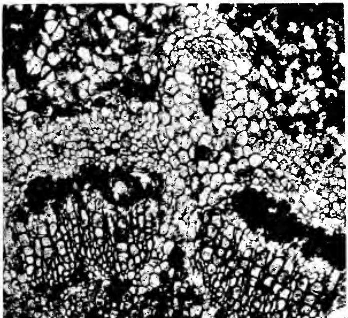

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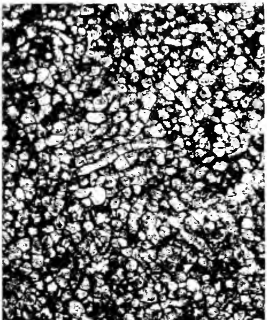

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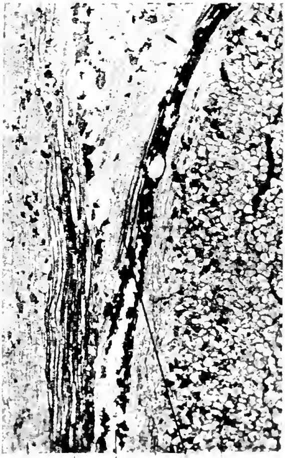

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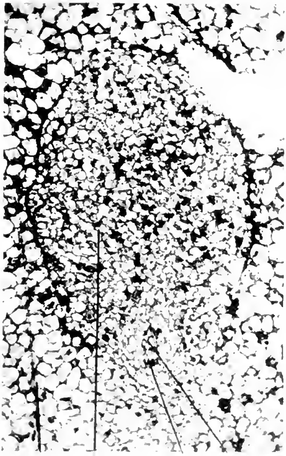

m.c. m.c.r. ph. x.

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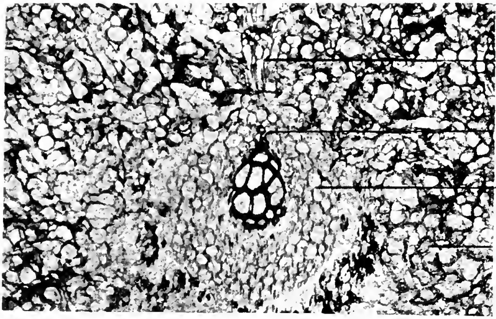

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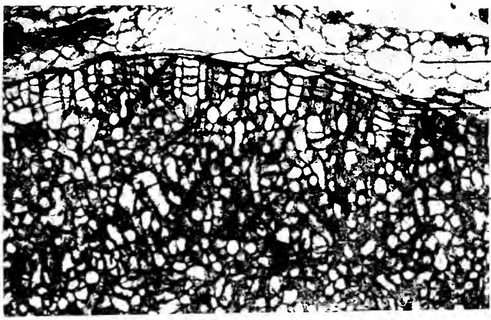


Manchester Memoirs, Vol. xlvi. (1902), *No.* **10**.

THE WILDE LECTURE.

X. On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion.

By HENRY WILDE, D.Sc., F.R.S.

(Delivered February 25th, 1902.)

The doctrine of the gradual evolution of the mental faculties from small origins of trial and error finds so many illustrations in the history of the natural sciences, that it is absolutely essential to further progress to review, from time to time, some of the foundations upon which the vast superstructure of modern knowledge now rests.

It will be universally allowed that if one of the Simiidæ could be taught to enunciate a false proposition, *e.g.*, that space is four dimensional, or that the twentieth century commenced on January 1st, 1900, such a creature would be much more interesting to naturalists, and be more highly valued by collectors, than any of its inarticulate companions of the forest.

History abundantly shows that every department of knowledge has passed, in a greater or less degree, through the evolutionary stage here illustrated, until more extended observation and experience have brought ideas into exact agreement with the things represented. This conformity of ideas to their archetypes constitutes the essence of truth, the ultimate object of all scientific enquiry. So unequal, however, is the correlation of growth of different kinds of knowledge in individuals, that men of the highest attain-

March 26th, 1902.

ments and distinction are to be found all over the world, whose minds are permanent receptacles of the greatest absurdities.

Although Bacon and Locke have designated such idiosyncrasies as a kind of insanity,* yet, in the light of modern knowledge, they mark a well-defined stage of mental development, and would be better expressed by the term simianisms, as indicating their lowly origin, and to differentiate them from dementia on the one hand, and the ratiocinations proper of *Homo sapiens* on the other.

One of the greater evils arising out of this unequal growth of the mental faculties, is the power of obstruction and of regression exercised by the simianism of the race, to arrest the growth of new knowledge when advanced in opposition to dominant opinions. It has been well said that truth has no greater power of propagating itself than error, and it has been repeatedly suppressed for ages over large geographical areas; but as error is ever capricious, while truth is unchangeable, some one of its appearances may fall upon a time favourable to its reception and make such progress as to withstand all subsequent attempts to uproot it.

A survey of the history of the great scientific discoveries which have benefited humanity, but have been established in opposition to prevailing opinions, will show that the low standard of intellect that was incapable of perceiving a new truth, when presented for acceptance, is generally associated with a like standard of morals when in active antagonism to such truth. These observations find abundant application in connexion with certain fundamental principles of motion which form the subject of this discourse.

* *Novum organum*. Book I. Aphorism 10.
Locke, *Human Understanding*. Book 2. Chap. 11, § 13.

Notwithstanding the numerous demonstrations that have been given of the diurnal rotation of the earth on its axis, the doctrine is comparatively of too recent origin in the world's history to obtain universal acceptance, or even by many of the educated classes. Considering that Roman ecclesiasticism has, up to the present time, made no formal pronouncement in favour of the doctrine, either by the canonization of Copernicus and Bruno, or by the erection of monuments to Kepler and Galilei, it is not surprising that attempts should be made from time to time to revive the simian idea of the immobility of the earth and the geocentric system of the universe. These attempts may afford amusement to some, or be thought unworthy of attention by those engaged in the more profitable work of enlarging the boundaries of science, but, from an educational point of view, they are not to be lightly dismissed, as the greater part of man's knowledge is derived, not so much from the evidence of things themselves, as from those authorities who profess to have obtained such evidence at first hand.

The pendulum and gyroscopic experiments of Foucault are the latest as well as the most brilliant demonstrations of the axial rotation of the earth that have yet been presented to the world. That they are the most convincing is evident from the fact that the rotation can be made visible in a room or below the surface of the earth. It has also been further shown that the times of the apparent rotation of the pendulum are in proportion to the sines of the latitude. Thus the motion of the plane of oscillation whereby the pendulum appears to turn round the vertical line in the same direction as the celestial bodies, *i.e.*, in the opposite direction to that of the rotation of the earth, would complete an entire revolution at the poles in twenty-four hours, the motion

vanishing at the equator previous to changing its direction in the southern hemisphere. Experiments have shown that in the latitude of Bristol, 51° 28′ N., the rate of rotation is about 11°·75 per hour = 30·7 hours for a complete revolution.* At Colombo, Ceylon, Lat. 6° 56′ N. the rate of rotation was found to be 1°·87 per hour = 192 hours per revolution.†

A few years after the publication of Foucault's experiments, I designed a gyroscope of larger dimensions than those generally constructed, which not only exhibits the earth's rotation, but also other principles of motion that have not so far been demonstrated by that instrument.

It consists of a heavy disc of gun-metal, six inches diameter, and weighs 4·5 lbs. The spindle on which it revolves is mounted in rings so as to turn freely in any direction. The disc, with its rings, can be supported in the usual manner from below, or be suspended on knife edges from above by means of a fine wire, according to the property of the rotating body it is desired to illustrate. Motion is given to the disc by means of a friction wheel driven by an electro-motor or by a cord unrolled from its axis.

When the disc is rapidly rotated, the vertical plane of rotation appears to turn horizontally round the vertical line, in the same direction as the stars, and in the same manner as the plane of oscillation of a pendulum, from which the diurnal rotation of the earth in the opposite direction is inferred. I have, however, found that the axial rotation may be made directly visible to an audience, by projecting a vertical band of light from the slit of an electric lantern upon a small mirror attached to the vertical axis of the gyroscope and from thence upon a screen. A black band

* *Phil. Mag.*, (4) Vol. 4, pp. 272-275.

† *Ibid.*, Vol. 2, p. 410.

is marked in a vertical position, on the central part of the screen, the horizontal motion of which across the parallel band of light, manifests the axial rotation of the earth directly as a sense impression. The rate of rotation of the black band for the latitude of Manchester is two-tenths of a degree per minute = 30 hours per revolution of 360°, $360° \div 24$ hours = 15° (Lat. 53° 29′ sine = ·804 × 15° = 12° per hour nearly = $360° \div 12° = 30$ hours).

Correlated with the doctrine of the diurnal rotation of the earth is Halley's hypothesis of the differential rotation of its internal parts about the same axis, to account for the secular variation of the mariner's compass.* From observations of the variation, the illustrious astronomer inferred that the direction of the internal motion was westward, and, consequently, that the rotation of the inner sphere was slower than the external shell of the earth. From further observations, he concluded that the internal sphere made one revolution backwards in 700 years.

Halley was quite alive to the objection that would be taken to his hypothesis, and anticipated it by instancing the ring of Saturn, as showing a continuous body rotating concentrically with a planet and having an interval of space between them. He further remarks that if this ring were turned on one of its diameters, it would then describe such a concave sphere as he supposed the external shell of the earth to be. Had Halley been living at the present time, he would not have failed to find further confirmation of the truth of his theory from the equatorial regions of the sun rotating at a different velocity from that of the regions nearer the poles, as observed by Carrington

* *Phil. Trans.*, Vol. xvii. 1692. Abridgment, Vol. iii., p. 470.

and others. This differential motion, as is well known, presents an obstacle in the way of determining the exact time in which the sun revolves on his axis. *

While the merit of suggesting the earth's internal rotation as the cause of the secular variation of the declination is entirely due to the genius of Halley, the particular disposition of his internal spheres, as well as his hypothesis of magnetic poles rotating with them, are not explicable by any known principles of science. Electro-dynamics, electro-magnetism, and the physics of the earth's crust were unexplored regions to seventeenth-century philosophers, without knowledge of which sciences Halley's theory admitted of no further development.

In a paper which was read before the Royal Society in 1890, I showed that all the principal phenomena of terrestrial magnetism, and the secular changes in its horizontal and vertical components, could be demonstrated on the assumption of an electro-dynamic substance (liquid or gaseous) rotating within the crust of the earth in the plane of the ecliptic, that is to say, at an angle of 23·5 degrees. By means of some new electro-mechanism, which I named a "Magnetarium," the slow period of backward rotation of the internal electro-dynamic sphere required for the secular variation of the magnetic elements, on different parts of the terraqueous globe, was found to be 960 years

The striking analogies between the action of a compass needle and a gyroscope have been pointed out by several writers, as, from the fixity of its plane of rotation, the

* That a high value was set on Halley's theory of the rotation of the internal parts of the earth, and that it was intended to be handed down to posterity, is evident from his fine portrait, which adorns the apartments of the Royal Society, being embellished with the diagrammatic representation, from the *Philosophical Transactions*, of the terrestrial globe enclosing an inner sphere having the same common axis of rotation.

gyroscope might under some circumstances be actually used as a compass. But the most interesting of these analogies is seen in its resemblance to the variation of the magnetic dip with the latitude. Thus the maximum dip is located at the magnetic poles of the earth and diminishes towards the magnetic equator, where it is nil, before changing its direction in the southern hemisphere in a manner similar to the variable motion of the pendulum and the gyroscope with the latitude, and the change of the direction of rotation south of the terrestrial equator.

Just as the pendulum and the gyroscope furnish the most decisive proofs of the diurnal rotation of the earth on its axis that have yet been adduced, so the secular variation of the magnetic elements, as demonstrated by the magnetarium, are equally decisive proofs of the rotation of the internal parts of the terrestrial globe in accordance with Halley's theory and as confirmed by my own experiments. Hence the gyroscope and the magnetarium are instruments complementary to each other for demonstrating the rotations of the exterior and interior parts of the earth respectively.

Notwithstanding that two centuries have elapsed since the Royal Society published Halley's paper on the motion of the internal parts of the earth as the cause of the magnetic variation, his theory has since made far less progress than the heliocentric system of astronomy after it was revealed to the world by Copernicus.* In the light of modern knowledge, there is little room for doubt that the slow progress made in this department of astronomical physics is due to the survival of the simian idea of the absolute immobility of the earth, and of the diurnal rotation of the celestial bodies. This idea, from the persistency

* *De Revolutionibus Orbium Cœlestium,* Lib. I, Cap. 10, p. 9. 1543.

of sense impressions, extending over many thousands of years, is almost instinctive, and a long course of mental training will yet be required before it is eradicated from the civilised world.

In my papers on the causes of the phenomena of terrestrial magnetism no indication was given of the source from whence the earth's magnetism might be derived. I now avail myself of this opportunity to supply the omission by assuming that the friction between the external and internal parts of the earth, rotating with a differential motion, is competent to generate the necessary quantity of electricity, as in the case of Armstrong's hydro-electric machine.

The like explanation is also applicable to account for the generation of the electricity of the sun, by the friction produced by the differential motions of its external and internal regions and manifesting itself in the solar corona. Moreover, the interruptions in the symmetry of the corona are coincident with the discharge of elementary vapours through sun-spot apertures, the greater amount of asymmetry being also coincident with the maximum period of sun-spot frequency. Hence the causal connection existing between sun-spots, terrestrial magnetic disturbances, and the display of electrical auroras in comparatively low latitudes.

The axial rotation of the moon during its synodical revolution, by which it always presents the same part of its surface to the earth, is so axiomatic that it might appear almost superfluous to offer any further demonstration of its reality beyond those already given by astronomical writers. So slow, however, is the growth of scientific ideas, that an individual examination of any large body of conventionally educated persons, would show that

but a small percentage of their number would have an intellectual perception of this simple astronomical truth. Hence the sporadic attempts that are made at different times to disprove the truth of the moon's axial rotation as well as the diurnal rotation of the earth.* Now the gyroscope affords another demonstration in addition to those already given, and is valuable in presenting negative, as well as positive, proof of the rotation of the moon by showing its synodical revolution without axial rotation.

Let a small globe or other symmetrical object be placed in the centre of a table, and let the gyroscope, at rest, with its stand, be moved horizontally in a circle round the globe, so that the same face of the disc and one side of the stand are always presented to the central globe, in like manner as the moon does to the earth. A spectator outside the circle, will then see every part of the disc in succession just as if he were placed outside the moon's orbit. Now if the disc be rapidly rotated, to preserve the fixity of its vertical plane of rotation, it will revolve round the central body without rotating on its axis; the relative positions of the bodies will now be reversed, as every part of the disc will present itself in succession to the central globe, while the same face of the disc will always present itself to a spectator outside the circular orbit. Moreover, the stand on which the vertical spindle of the gyroscope is supported will make one revolution round the stationary vertical spindle during its orbital motion round the globe, thereby affording, simultaneously, positive and negative proof of the moon's axial rotation during its synodical revolution.

In few departments of knowledge has the antagonism between the simianism of the race and natural truth been

* De Morgan's *Budget of Paradoxes*.

more in evidence than in the controversy respecting the measure of moving force, which has exercised the minds of distinguished men of science and learning for more than two centuries.

Long before the time of Descartes, the common experience of mankind in the mechanical arts had shown that unequal weights at each end of a lever of the first order balanced each other, as in the Roman and Chinese steel-yards, and that the spaces through which a large and a small weight oscillate are in proportion to the weight and length of the lever on each side of the fulcrum and have a ratio of equality. The motions of other connected bodies and machines for raising weights demonstrated to these ancient observers, as clearly as the sun appeared to them to go round the earth, that the force of a body in motion was simply as the velocity. Hence the origin of the proposition enunciated by Descartes in his *Principia*,* "That when a part of matter is moved with double the quickness of another, and that other is twice the size of the former, that there is just precisely as much motion, but no more, in the less body as in the greater." Whence also we see the *a priori* application by Descartes of the vulgar measure of the moving force of connected bodies, and the principle of virtual velocities, to bodies moving by the free action of gravity of which he had no experience.

Forty years later, Newton adopted in his *Principia* Descartes' definition of the quantity of motion in a moving body in the following terms:—"The quantity of motion is the measure of the same arising from the velocity and quantity of matter conjointly. The motion of the whole is the sum of the motion of all the parts; and therefore in a body double in quantity with equal

* *Principia Philosophiæ*, part 2, § xxxvi, 1643.

velocity, the motion is double; with twice the velocity it is quadruple." To make this definition more explicit, Newton states under his second law, "If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, *whether that force be impressed altogether and at once, or gradually and successively.*"*

Although Galilei had long before demonstrated that the spaces described by heavy bodies from the beginning of their descent are as the squares of the times, and as the squares of the velocities acquired in falling through those spaces, yet the significance of this law in relation to the moving force of bodies was entirely overlooked until Leibnitz made the announcement, in 1686, that the force of a body in motion, by the free action of gravity, is as the square of the velocity. To this measure of moving force Leibnitz applied the term *vis viva*, or living force.

That Newton failed to recognise that the spaces through which a body moved by the free action of gravity were a measure of moving force, is seen in the scholium to his third law of motion, wherein it is stated that, "When a body is falling, the uniform force of its gravity acting equally, impresses, in equal particles of time, equal forces upon that body, and therefore generates equal velocities; and in the whole time impresses a whole force and generates a whole velocity proportional to the time." Maclaurin, the pensioned defender of the Newtonian philosophy, also states that, "When a body is projected upwards with a double velocity, the uniform impulses must be continued for a double time, to be able to destroy the motion of the body; and hence it arises that the body, by setting out with a double velocity, and ascending for a double time, must arise to a quadruple height before its

* Newton's *Principia*, Def. 2, Law 2.

motion is exhausted. But this proves that a body with a double velocity moves with a double force, since it is produced or destroyed by the same uniform power continued for a double time, and not with a quadruple force, though it arise to a quadruple height." He adds that "This, however, was the argument upon which Mr. Leibnitz first built this doctrine."*

The controversy that has since raged round this question, and which is still unsettled, forms a remarkable chapter in the history of the physical sciences. As might have been anticipated, *a priori* philosophers, mathematicians, metaphysicians, and men of letters, unskilled in experimental methods of interrogating nature, adopted the vulgar measure of moving force. Of these may be mentioned, besides Maclaurin, Emerson, Hutton and Young; Locke, Kant, Schopenhauer, Reid and Voltaire. Happily for the progress of science a small number of philosophers, among whom Smeaton and Wollaston stand pre-eminent, proved conclusively, by various methods, that the true measure of the moving force of a body under the free action of gravity is as the square of the velocity. Nevertheless, modern scholasticism has not yet pronounced in favour of the law, at least in this country, and the ingenuous youth of universities and schools are still left in error and ignorance of a principle of motion which lies at the very root of the natural sciences.

An unpleasant feature of this controversy was the arrogance with which the experimental results of Smeaton and Wollaston were treated by their opponents, and in this respect a close parallel is found in the attitude of seventeenth-century science towards the Copernican system of astronomy.

The facts adduced by the earlier supporters of the

* *Account of Newton's Philosophical Discoveries*, 1748, p. 135.

Leibnitzian measure of moving force were (1) that a body with a double velocity will overcome the resistance of four springs, one of which alone is equivalent to the force of the same body moving with a velocity as one; (2) that a body falling with a velocity of two will penetrate a soft body four times the depth of the same body with a velocity as one; (3) that if a non-elastic body moving with a given velocity strike another equal body at rest in free space, they will move on together after impact with half the velocity of the first body, while one-half the force of impact is lost in producing change of figure. The first and second instances were met by the opponents of the *vis viva* measure affirming that the forces generated by the double velocities were destroyed in a double time (notwithstanding Newton's second law in which it is laid down that the effect is independent of the time), while in the third instance it was denied that there was any loss of molar motion from change of figure, and that, as the two bodies moved together with half the velocity, the quantity of motion was the same as before collision, in accordance with the definition of Descartes and of Newton.

Maclaurin expresses this point of the controversy with singular lucidity.—"Now the difficulty was, how to account for the loss of one half of the force of the first body in the stroke: for this purpose they [the Leibnitzians] advanced, without any other proof, this new doctrine, that when the parts of soft bodies yield without restoring themselves, being void of elasticity, a certain quantity of force is lost in the compression of their parts by the collision: whereas we know no way by which force is lost in one body, but by its being communicated to another. The parts of soft bodies are indeed moved out of their places, in the collision, and some motion is lost in the first body being communicated, in this manner, to the parts of the second; but these

parts cannot lose their motion otherwise than by communicating it to other parts, or by its accruing to the whole body; so that there is no just reason for supposing that any motion or force is lost in flattening or hollowing of soft bodies, in their collision; and this new tenet is invented merely to serve a particular purpose."*

Smeaton, with his accustomed ingenuity, devised an elegant method of reproducing the effects of the collision of inelastic bodies and measuring exactly, by means of springs, the force spent in producing change of figure.† Although his demonstrations were published more than a century ago, they are still ignored and controverted by many writers upon natural science. The modern editions of Hutton's valuable treatise on pure and applied mathematics are still disfigured by the same formula for the collision of inelastic bodies as for those which are elastic. Young also, in his classical lectures on natural philosophy,‡ repeats the same error when dealing with the collision of inelastic bodies, and affirms that the sum of the momenta is the same after collision as it was before collision. It is hardly necessary for me to point out to members of this Society that the loss of force referred to by the term "change of figure" is the transformation of the molar motion of bodies into the molecular motion of heat.

Among the more recent professors of natural philosophy who have given their support to the Cartesian measure of moving force are Dr. Lardner (1851), Clerk Maxwell (1876),§ and P. G. Tait (1899).‖ The following paragraphs, 195, 251, 252, from a widely-known handbook of natural science by Dr. Lardner, who was

* Maclaurin's *Account of Newton's Philosophical Discoveries*, 1748. p. 118.

† *Phil. Trans.*, Vol. LXXII., 1782.

‡ *Lecture VIII.*

§ *Matter and Motion.*

‖ *Newton's Laws of Motion.*

sometime professor of natural philosophy at London University College, are remarkable as the logical outcome of measuring the quantity of motion of a moving body by its mass and velocity conjointly. "It appears, therefore, that the velocity or force with which a falling body strikes the ground increases in much less proportion than the height from which it falls. If the height be augmented in a fourfold proportion, the force of the fall will only be augmented in a twofold proportion. This explains a fact of not unfrequent occurrence, and which sometimes produces surprise. Persons sometimes fall or leap from such heights as would seem to render their destruction inevitable, yet they are frequently found to escape without considerable injury. This is explained by the fact that the momentum, or shock produced by the fall, increases in a proportion so very much less than the height." And again, "the force with which a ball weighing an ounce and moving at ten feet per second will strike any object, will be exactly ten times the force with which the same ball moving at one foot per second would strike such an object." He adds that "These fundamental principles are so obviously consistent with universal experience that they can scarcely be said to require proof." The simple dogmatism of this last statement still finds expression in classical text-books on the laws of motion of the present day.

Metaphysicians and men of letters, as I have said, have been peculiarly unfortunate in their attitude towards the Leibnitzian measure of moving force. Schopenhauer, in Haldane and Kemp's translation of his work entitled *The World as Will and Idea*,* supports the Cartesian measure by the following illustration. "A hammer weighing six pounds with a velocity = 6, in

* Note to *Prædicabilia a priori of Matter.* (Vol. 2, pp. 226-227).

driving a stake into the ground, effects as much as a hammer weighing three pounds with a velocity = 12, for in both cases the quantity of motion or the momentum = 36." Now the experiments of Smeaton, Wollaston and others have shown that the real effect in this case would be $6 \times 6^2 = 216$ and $3 \times 12^2 = 432$, or double the depth of penetration for the higher velocity than that arrived at by the German psychologist. His further comments, however, on the quantity of motion in a body are highly significant, as he states that "the same law lies at the foundation of the theory of the lever and of the balance. For here also the smaller mass on the longer arm of the lever or bearer of the balance has a greater velocity in falling; and multiplied by this it may be equal to, or greatly exceed, the *quantity of motion* or the *momentum* of the greater mass at the shorter end of the lever." He adds that "the substance of this doctrine has long ago been expressed by Newton and Kant."

We have thus another striking example of an acute thinker applying, in common with Descartes and other philosophers, the Romano-Chinese measure of the motion of connected bodies to those moving by the free action of gravity.

Bewildered by the contradictions of natural philosophers, Voltaire, Reid and other writers have professed to see further into both sides of the controversy than those actually engaged in it, and, with the least amount of trouble to themselves, have made a show of superior wisdom by declaring that the dispute was entirely verbal. The latest instance of this easy method of dealing with the question is to be seen in a recent exposition of the philosophy of Leibnitz by the Hon. B. Russell (1900), wherein it is declared (p. 77) that "this controversy seems to modern mathematicians to be mere logomarchy."

The members of this Society, as might have been expected, would not look with indifference upon a dispute which affected so vitally the foundations of mechanical science. Thus we find in Vol. VII. of the *Memoirs* a paper which was read before the Society by Peter Ewart (1808), wherein the Leibnitzian measure of moving force is supported with great ability. So highly did Dalton estimate the value of this paper that he dedicated to its author the second edition of his *New System of Chemical Philosophy*, "on the score of friendship, but more especially for the able exposition and excellent illustrations of the fundamental principles of mechanics in his essay on the measure of moving force." Ewart expresses in his paper his indebtedness to Dalton for proposing an experiment in order to show that the same effect is produced by the same force, whether in act by gradual pressure or by sudden percussion, in accordance with Newton's second law of motion which has been so persistently ignored by the zealous advocates of the Cartesian measure of force.

The continuity of ideas developed by this Society in favour of the Leibnitzian measure of force is further seen in Joule's determination of the mechanical equivalent of heat, by which the temperature of one pound of water is raised 1° F. by the fall of one pound weight through a space of 772 feet, or 772 lbs. from a height of one foot, irrespective of the time of the falling weight. That Joule was an uncompromising opponent of the Cartesian measure of force is evident from his having headed his classical paper on the mechanical equivalent in the *Philosophical Transactions* with the quotation from Leibnitz that "*The force of a moving body is proportional to the square of its velocity or to the height to which it would rise against gravity.*"

Several interesting illustrations of the principle of *vis*

viva, in marked contradiction to those of Schopenhauer and Dr. Lardner, were given by Joule in the course of a lecture delivered in 1847,* in which he states that, "a bullet fired from a gun at a certain velocity will pierce a block of wood to only one quarter of the depth it would if propelled at twice the velocity, and that four times the weight of powder would be required in the latter case than in the former." Thus, also, a railway train going at 70 miles per hour possesses 100 times the impetus, or living force, that it does when travelling at 7 miles per hour.

The latter illustration was fully confirmed by Fairbairn, who brought before this Society, in 1859, the results of some experiments in which he was engaged, on continuous brakes for arresting the motion of railway trains.† The brakes were applied when the train was running on a level line at different velocities, with the average results estimated as follows:—

20 miles per hour	....	24 yards.
30 " "	....	53 "
40 " "	....	94 "
50 " "	....	147 "
60 " "	....	212 "

From this Table it will be seen that the distances the train ran after the brakes were applied were as the square of the velocities.

The brief account here given of the contributions to this historic controversy by members of this Society would hardly be complete if I omitted the review of Ewart's paper by Eaton Hodgkinson, F.R.S., published in Vol. XII. of the *Memoirs*, an abstract of which also appears in Dr. Angus Smith's *Centenary of Science in Manchester.*‡

* *Manchester Memoirs*, Vol. XXXVI., p. 5.

† *Proc. Manchester Lit. and Phil. Soc.*, Vol. I., p. 178.

‡ *Manchester Memoirs*, Vol. XXIX., pp. 253-256.

In this review, the author, while expressing his high opinion of Ewart's scientific attainments and labours, manifests his inability to do justice to the subject of which he had been requested to give an account. He confuses the moving force of bodies under the free action of gravity with that of connected bodies, as in the work done by machines; echoes the opinions of those who maintained that the dispute was only about terms, and characterises as assumptions the clear demonstrations of Smeaton, Wollaston and Ewart of the loss of moving force in the collision of inelastic bodies, which is now common knowledge.

The greater number of experiments on the measure of moving force, as will be seen, were made with rectilinear motions, until Smeaton found, in the course of his engineering undertakings, the great difference between accepted theory and actual practice, and undertook a series of experiments on the rotatory motions of bodies which confirmed, in the most complete manner, the results previously obtained with rectilinear motions.*

Although the proportion of moving force necessary for giving different velocities to bodies rotating about an axis was completely demonstrated by Smeaton, yet, the design of his experimental machine, which involved the motion of several of its parts in addition to the falling weights used therewith, failed to satisfy the critical accuracy of Atwood and other opponents of the *vis viva*, who made the most of the small differences between the theoretical results and those obtained from Smeaton's experiments. Now, the gyroscope, from the fewness and simplicity of its parts, affords the means of determining the moving force of a body in a decisive manner, as the

**Phil. Trans.*, Vol. LXVI., 1776. Abridgment, Vol. 14, p. 72.

only disturbing element to be accounted for is the small amount of friction at the centres of rotation.

The method of experimenting with the instrument was as follows :—The ring in which the disc rotates was firmly supported in a horizontal position, and at a sufficient height to permit two weights of 0·5 lb. and 2 lbs. each to fall through spaces of 30 inches and 120 inches respectively. The diameter of the spindle on which the disc revolved could be doubled, as required, by means of a loose cylinder secured thereon and carried round with the spindle. Motion was given to the disc by means of a fine thread closely wound on the spindle without the turns overlapping each other. The weights were attached directly to one end of the thread, while the other end terminated in a loop to slip over a small pin projecting from the spindle in the usual manner. The time in which the thread was unwound from the spindle at the commencement of the fall of the weight, to the time when the last turn of the thread left the spindle, was determined with precision by means of a stop watch.

With the smaller weight and a fall of 30 inches, it was found that the friction of the centres of rotation increased the time of descent by nearly half a second, as in Smeaton's experiments, but as this retardation was not observable in experiments with the larger diameter of the spindle and with the greater weight, the discrepancy has been eliminated from the table of results. The number of revolutions of the disc per minute was calculated from the observed times of revolution at a low velocity, and also from the time of descent into the number of turns of the thread on the spindle and twice the uniform rate of revolution for the final velocity, in accordance with the law of acceleration of moving bodies from a state of rest.

No.	Weight in lbs.	Diameter of Spindle-inch.	Height of fall in inches.	Turns of Thread on Spindle.	Time of descent in seconds.	Revolutions per minute.
1	0·5	0·452	30	21·0	13·00	194
2	2·0	0·452	30	21·0	6·50	388
3	0·5	0·452	120	84·0	26·00	388
4	2·0	0·452	120	84·0	13·00	776
5	0·5	0·904	30	10·5	6·50	194
6	2·0	0·904	30	10·5	3·25	388
7	0·5	0·904	120	42·0	13·00	388
8	2·0	0·904	120	42·0	6·50	766
1	2	3	4	5	6	7

The principal results shown in the above Table, which are the average of a number of experiments, are :—

1. From a constant height of fall and diameter of spindle, the weights are as the square of the velocities of descent and of the number of revolutions of the disc.

2. For constant weights, the spaces through which the weights fall are as the square of the velocities generated.

3. The times of descent and the number of revolutions, with the same diameter of spindle, are inversely as the square of the weights and of the spaces through which the weights fall.

4. For constant weights and heights of fall, the times of descent are inversely proportional to the diameter of the spindle, while the number of revolutions remain the same for both diameters.

5. The times of descent of the smaller weight in experiments 5 and 7 are the same as those in 2 and 4 with the larger weight, in which, for the same height of fall, the number of revolutions is doubled respectively. This result is decisive as against the arguments brought forward by Maclaurin and others to explain away the Leibnitzian measure of moving force by substituting the element of time for the space through which a moving body acts.

Another demonstration of the absurdity of measuring the momentum of a moving body by its mass and velocity conjointly, is, by a method of equals, applied to the case of four gyroscopes of precisely similar construction to the one described. Let, therefore, four such instruments be set in motion simultaneously by the fall of four weights of 0·5 lb. each through a space of 30 inches, to generate 194 revolutions of the discs per minute, as in experiment 1 in the Table. It will readily be allowed that there are here four units of body and four units of motion according to the definitions of Descartes and Newton. If now a fifth similar gyroscope be set in motion by the fall of a weight of 2 lbs. through the same space of 30 inches, the rate of descent of this weight will be double the rate of descent of the weights of 0·5 lbs., and will, consequently, generate a double velocity of rotation, or 388 revolutions of the disc per minute, as in experiment 2 in the Table. Hence the quantity of motion in the disc, rotating with a double velocity, is equal to the sum of the motions of the other four discs rotating simultaneously with half the velocity. But the quantity of motion in two of the discs, according to Descartes and Newton, is equal to the motion of one disc rotating with a double velocity, which is absurd; therefore, the force of a body in motion by the free action of gravity is as the square of the velocity.

Another obstacle which operates at the present time

to prevent the modern student of rational mechanics from obtaining a comprehensive view of the principles of motion, is the change that has recently been made in the signification of the name *vis viva.* The term *momentum* is admitted on all hands to be synonymous with the *quantity of motion* of Descartes and Newton. It will also be allowed that the term *energy* (kinetic energy), first applied by Young to the product of the weight of a body into the square of its velocity, is synonymous with the *vis viva* of Leibnitz, as it was so affirmed to be by Young.* Nevertheless, recent writers have arbitrarily degraded the *vis viva* or *energy* of a body to one half its original value, while still retaining the same name. † The liberty so taken with this fundamental principle of motion may be fairly comparable with the action of an over-enterprising trader who should, in like manner, reduce the imperial standard of weights and measures to his own advantage. Now, whatever assumed convenience (apart from actuality) this change in the value of the *vis viva* might have in relation to the duty of motors and machines through which mechanical force is transformed into heat or other mode of force, and where the work done is admittedly as the velocity, the final result, if not indeed the actual object, of reducing the *vis viva* of Leibnitz to one half its value was to bring it into agreement with the Cartesian and Newtonian *quantity of motion* or *momentum* with which it is absolutely irreconcilable.

Much of the opposition to the Leibnitzian measure of moving force has doubtless arisen from the apprehension that the Newtonian law of gravitation would be invalidated

* *Lectures on Natural Philosophy*, Lecture VIII.

† Moseley's *Engineering and Architecture*, p. viii, 1843.
Matter and Motion, J. Clerk Maxwell, 1876, p. 79.
Newton's Laws of Motion, P. G. Tait, 1899, p. 27.

by its acceptance. The ground for this opinion was that the principal lunar and planetary motions were already well explained by Kepler's third law, the law of falling bodies discovered by Galilei, and the hypothesis of central forces acting at some function of the distance as assumed by Hooke and others. Hence the small progress that the law of gravitation, as the inverse square of the distance, made at Cambridge and on the Continent during the lifetime of its discoverer.

Newton's first law of motion, from its common acceptance, appears to be so self-evident that a denial of its universality would, at first sight, indicate a spirit of perverse contradiction rather than a serious desire to elucidate the truth of nature. Nevertheless, as will be seen, the common idea of *inertia*, like the simian notion of the immobility of the earth, and the Cartesian quantity of motion in a body, has its origin in an erroneous interpretation of phenomena as presented to the senses.

It is laid down by Newton in his first law of motion that "*Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.*" "Projectiles persevere in their motions, so far as they are not retarded by the resistance of the air or impelled downwards by the action of gravity. A top, whose parts by their cohesion are perpetually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air."

Commenting on this law, Maclaurin states,* "It is part of the same law, that a body never changes the direction of its motion, of itself, but by some external influence only, and it is as natural a consequence of the

* *Account of Newton's Philosophical Discoveries*, p. 113.

passive nature of body, as that it never changes its velocity of itself. As body has no self-motive power, or spontaneity, if it were to change its direction, how could it," he asks, "determine itself to any one direction rather than to another?"

Now, no one will be found to deny that gunpowder nitroglycerin, or other endothermic substance is a body according to Definition I. and Law I. of Newton's *Principia*. The experiments of Fairbairn, an account of which was read before this Society in 1859,* have shown that gunpowder, under great pressure, becomes a hard compact mass with a smooth and shining surface. Let, therefore, a mass of this explosive, the same weight as the disc of the gyroscope (4·5 lbs.) be pressed into a mould of similar form and mounted on a spindle. Such a disc, or spinning top, to use Newton's illustration, would exhibit all the phenomena of rotation, qualitatively and quantitatively, as if it were formed of gun-metal. If now, when the disc is in rapid motion, an electric spark be transmitted from a conductor through the disc, the rotatory motion of the body will be suddenly arrested, not by external mechanical impulse, but by its own spontaneous motion, or internal force. In like manner, if the disc or other endothermic body were projected upwards through the air by some mechanical means, at the rate of 100 feet per second, and if an electric spark were transmitted through it by wires carried by the body during its ascent, the upward motion would immediately cease, and the molecules of the body would project themselves, spontaneously, in every direction as in the case of the rotating endothermic disc. Moreover, the molecular motions of the gaseous products, created by the explosion, would continue active for an indefinite length of time, until these products entered into new chemical combinations.

* *Proc. Lit. and Phil. Soc. Manchester*, Vol. I., p. 117.

That the spontaneous motion of an endothermic body is independent of its motion of translation, is evident from its explosive power when in a state of rest, while the quantitative difference between the two motions is extremely great. The effective endothermic force of the same weight of gunpowder as the disc of gun-metal, (4·5 lbs.) is equal to 2200 foot-tons,* while the impressed motion of the disc, generating 776 revolutions per minute, by the fall of 2 lbs. through a space of 120 inches = 20 foot-pounds, is represented by the force of less than half a grain of gunpowder.

That the electric spark would have no influence on the quantity of motion generated by the explosion of an endothermic body, is evident from the fact that the spark does not impart motion to a heavy body at rest, its function in causing the explosion being similar to that of the signal which sets a battalion or a fleet in motion.†

Another legacy of error bequeathed by Descartes to an impressionable posterity is the dogma that the quantity of rest and of motion in the whole universe is at all times the same. This dogma is set forth in the same paragraph of his *Principia* as that containing his definition of the quantity of motion in a body, and has since been adopted by modern physicists under the term of "potential" and "actual" energy.

In his lecture on the *Conservation of Force*,‡

* Noble, *On Modern Explosives. Proc. Roy. Institution*, Vol. XVI., p. 330.

† Bishop Horsley, the learned editor and commentator of Newton, is quoted by Lord Monboddo in his "*Ancient Metaphysics*," and by Dugald Stewart in his notes on "*Theories of the Activity of Matter*," as saying that "*Newton's first law of motion cannot be defended on the principles of sound philosophy.*"

‡ Lecture delivered at Carlsruhe, 1862.

Helmholtz states that "the total quantity of all the forces capable of work in the whole universe remains eternal and unchanged throughout all their changes." Tyndall also, in his *Heat as a Mode of Motion*, says, p. 141, "To create or annihilate energy is as impossible as to create or annihilate matter, and all the phenomena of the material universe consist in transformations of energy alone."

Newton attempted to disprove the Cartesian doctrine of the conservation of motion, by showing that force was lost by letting two equal pendulums of lead or soft clay fall against each other. This demonstration, would not, however, be accepted at the present time, as the energy in this instance was transformed into the motion of heat. Molecular mechanics were unknown to Newton, and also to his followers for more than a century after the publication of the *Principia*.

That the quantity of motion and rest in the universe is not always the same now admits of an easy demonstration. Let it be granted that at any given moment the universe contains a definite amount of rest and motion, or, in other words, that all the static and dynamic forces in the universe are *in equilibrio*. Now, it will be evident that the explosion of our disc of gunpowder (4·5 lbs.) would add 2200 foot-tons of energy and motion to the sum previously existing. Moreover, if all the endothermic bodies on the planet were exploded at the same moment, the sum of their motions and energies would further increase the sum of the motions and energy of the universe.

Just as the molar and molecular *static* forces of bodies are identical with the state or force of *rest*, so also is the attribute or force of *motion* identical with the molar and molecular *dynamic* forces of these same bodies. It is therefore evident that, as a body cannot be at rest and in

absolute motion at the same time, the quantity of "rest" or "potential" of the endothermic body is annihilated simultaneously with the creation of motion and energy in the same body. In fine, the dogma that the quantity of rest and motion in the universe is at all times the same is one of those platitudes which, under the pretence of knowledge, evoked the ridicule of Locke,* and is equivalent to affirming that what a Cartesian knows, and that which he does not know, constitute the sum of all the knowledge in the universe, and that the sum-total of all the knowledge and of all the ignorance in the universe is a constant quantity. It will be evident that similar trifling equations may be multiplied indefinitely.

Just as the Cartesian principle of the conservation of molar motion fails entirely when applied universally, so also does the same principle fail in its universal application to the molecular motions of bodies, as I have already shown in my paper read before the Society in 1896.†

Although I have demonstrated the attribute of spontaneous motion and energy in endothermic bodies, the principle may also be well illustrated (1) by the heat generated through the explosion of gaseous mixtures and by other chemical reactions; (2) by discharges from statically electrified bodies and the Leyden jar; (3) the evolution of dynamic electricity from an electro-magnet after contact with the exciting machine is broken; (4) the generation of electricity from primary and secondary batteries; (5) the mechanical energies and motions generated by springs and by the free action of gravity.‡

* Locke, *Human Understanding*, Chap. VIII., *of Trifling Propositions.*

† *Manchester Memoirs*, Vol. XL., pp. 61-71.

‡ The difficulties and contradictions involved in applying the principle of conservation to the gravitating force have been stated at length by Faraday in a lecture dealing exclusively with the question. *Proc. Roy. Institution*, 1857.

Even in those cases where bodies apparently move by impulse, as in the collision of elastic bodies, the principle of spontaneous motion may not be altogether excluded, for the reason that the motion of a body, after impulse, is the same as that of a body moving by volition. This is well exemplified in the case of a cyclist who, when riding on a machine, moves by *volition*, but when losing control of it, moves by *impulse*, and again moves by volition on regaining control of the machine.

The demonstration which I have given of the spontaneous motion of endothermic compounds clearly shows that volition can no longer be held to be the exclusive attribute of the organised forms of hydro-carbon compounds. Nor can the same attribute be excluded from the beautiful crystalline bodies (as seen in nature and in the laboratory of the chemist) which they possess in common with the higher and the lower forms of organic life.

Just as the spasmodic and capricious movements of the organised forms of the hydro-carbon compounds create in the mind the idea of spontaneous motion, acting from within, so the regular and rhythmical motions of inorganic substances, under constant conditions, induce, in the earlier stage of man's intellectual development, the idea that such bodies only move by impulse, acting from without, and of necessity.

Recapitulation.—It has been shown (1) that the geocentric systems of Ptolemy and the older cosmogonists were founded on the simian idea of the immobility of the earth and the diurnal rotation of the celestial bodies. (2) That a comparatively small number of the world's population accept the heliocentric system of planetary bodies from an actual perception of its truth. (3) That

the like ignorance prevails in regard to the rotation of the moon on its axis during its synodical revolution. (4) That the Cartesian quantity of motion, or momentum, of a body, as the product of its mass and its velocity, was the vulgar measure of force used in the common arts of life from remote ages, and was applied generally, by Descartes and by Newton, to include bodies moving by the free action of gravity, of which they had no experimental knowledge. (5) That Newton's first law of motion, founded on the common belief in the absolute inertia of all bodies, is in contradiction to the spontaneous motions of endothermic substances and of the organised forms of the hydro-carbon compounds. (6 That the Cartesian dogma of the universal conservation of motion and rest is disproved by the volitional manifestations of energy and motion through the explosion of endothermic bodies and by other examples. (7) That the conservation of rest and motion is the determinate and limited expression of Infinite Will, and rests upon a different foundation from that of the conservation of substance, the creation or annihilation of which is unthinkable.

Although the rapid progress of the natural sciences during recent times is undoubtedly due to the close application of the mental faculties exclusively to enquiries connected with the molar and molecular qualities of bodies, yet, in dealing with universals, whether of space, body, or motion, it is impossible to avoid the subject of first and final causes, which is imminent at every turn, in taking a widely comprehensive view of natural phenomena. Thus, the principle of spontaneous motion brings before the enquiring mind the problem of the mode or modes of existence of these causes, as they are manifested in the religious ideas of the various races of mankind. In the no distant future, advancing civilization will imperatively

require a solution of these problems, intimately affecting, as they do, not only man's present and final happiness, but also the peace of the world. Meanwhile, whatever justification some men may find by remaining in doubt or suspense of judgment on these questions, the denial of the reality of primary and ultimate causes, in any and every mode of their existence, is a profound error, as well as an indubitable mark of a survival of the lowest stage of simian intellect. "Look out," says Hume, in his *Natural History of Religion*, 1755, "for a people entirely destitute of religion: if you find them at all, be assured that they are but a few degrees removed from brutes."

> "All nature is but art, unknown to thee;
> All chance, direction, which thou canst not see;
> All discord, harmony not understood;
> All partial evil, universal good:
> And spite of pride, in erring reason's spite,
> One truth is clear, Whatever is, is right."

It is not a little remarkable that, while so much thought and labour have been bestowed on the invention and use of instrumental appliances for the observation of natural phenomena, so little attention has been given to the powers and the action of that bodily instrument through which all things are perceived and all knowledge is derived. Hence the egregious errors which some specialists in the physical sciences fall into, when dealing with subjects in close relation to those in which they have acquired their well-merited reputations. Thus we find several of these modern disciples of Protagoras fixing limits to the universe, and numbering and weighing up all the celestial bodies contained therein, without any

knowledge of their distances or their magnitudes. Another of these specialists has persuaded himself, and holds forth, that meteoric stones are the *prima materia* of all self-luminous bodies in the universe, and, consequently, of all non-luminous bodies, including his own personality. Others, again, through the like neglect of mental philosophy, exhibit an abject credulity, through which they become the sport and dupes of vulgar pretenders to occult powers of spiritualism, clairvoyance, divination, and other forms of modern witchcraft.

The following definitions of some fundamental concepts of the universe may be of interest to those who desire to base their knowledge on the sure foundation of natural truth, unfettered by the simianisms of past generations.

Space:—The absolute void in which all existence is contained; its parts inseparable and immovable; infinitesimal and infinite in extent; uncreated and eternal. Hence the greatest immensity of space through which instrumental science can penetrate, is an infinitesimal compared with the illimitable space extending beyond.

Substance:—That absolute existence which is extended in space; its parts separable and movable; rests and moves, by volition, in an infinity of modes and degrees; co-infinite and infinitesimal with space, and eternal in duration. Should this definition of substance be considered inadequate, let him who would improve upon it, first determine the absolute magnitude of the centre of an actual solid of revolution; he may then be able to define the ultimate essence of substance.

Matter:—The mutable *qualities* and *forms* inherent in *substance*, as manifested in (1) the properties of the different series of the chemical elements and their compounds;

(2) the several forms of nebular, stellar and planetary bodies; (3) the crystalline and other forms of mineral species; (4) the organised forms of vegetable and animal life. All these qualities and forms which constitute matter are, individually, finite and destructible, but the species throughout infinite space are eternal. Should the infinity of substance and of matter, as herein defined, be denied, then, by the above definition of space, the quantity of substance and matter in the universe would be infinitesimal or less than any assignable quantity, compared with the illimitable space beyond, which is absurd.

Rest:—That state of substance, by which it remains in the same position absolutely in relation to infinitesimal and infinite space; but it is not affirmed that any part of substance is actually in a state of absolute rest. This definition includes the relative positions of bodies to each other and the molecular and molar statics of all bodies.

Motion:—That attribute of substance, with its modes, by which it changes its position absolutely in relation to infinitesimal and infinite space. This definition includes the relative motions of bodies to each other, and the molecular and molar motions of all bodies. Whence it follows that a body cannot be in absolute motion and at absolute rest at the same moment. Nor can there be any motion, or other modes or qualities, without substance notwithstanding the assertions of some idealists to the contrary.

Time:—Space, substance, matter, rest and motion are objective realities, whether the mind perceives them or not. But, as no one of these fundamental objectivities constitutes time, either in succession or in conjunction, the idea must consequently be sought for in the mind itself. Time, therefore, may be defined as that operation

of the understanding which compares, consciously or unconsciously, one series of motions or events with another series of motions or events. Hence it follows (1) that as time is a function of the mind, and its measures arbitrary quantities, the natural measure of the quantity of motion in a body is the space through which it moves under a constant resistance. (2) That the quantity of motion in a substance is not a subject of *a priori* reasoning, and might be, ontologically, as the third, or any power of the velocity. (3) That the past and the future have no real existence outside the mind of a conscious reflecting agent. (4) To Omniscience, the past and the future are an ever-abiding present.*

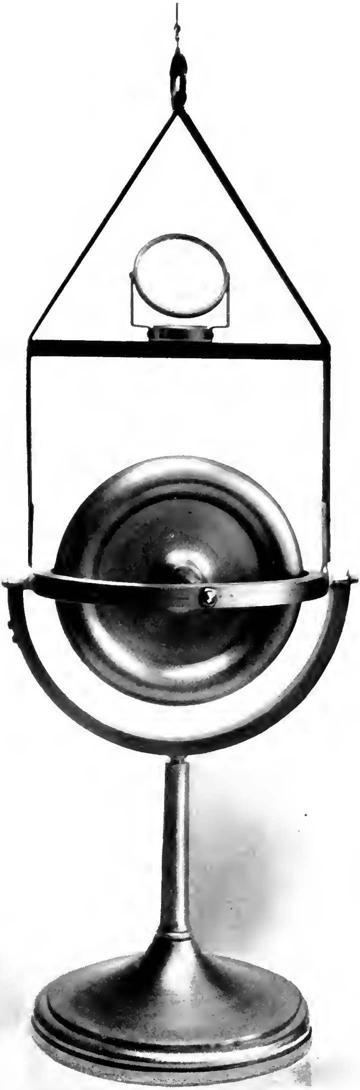
* Kant, Schopenhauer and other metaphysicians are agreed that time itself is a subjective form of the faculty of sense, but they have not succeeded in defining more precisely the nature of the idea.

EXPLANATION OF PLATES.

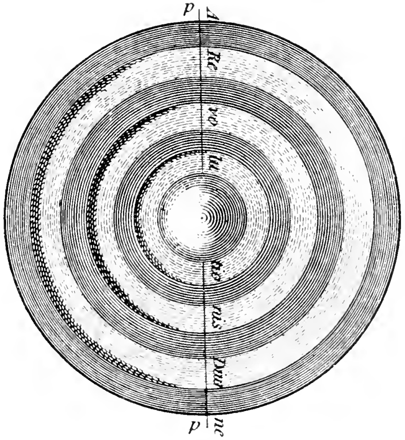
Plate XIV. Reflecting Gyroscope, for demonstrating the diurnal rotation of the earth on its axis.

Plate XV. Differential rotation and general constitution of the internal parts of the terrestrial globe.

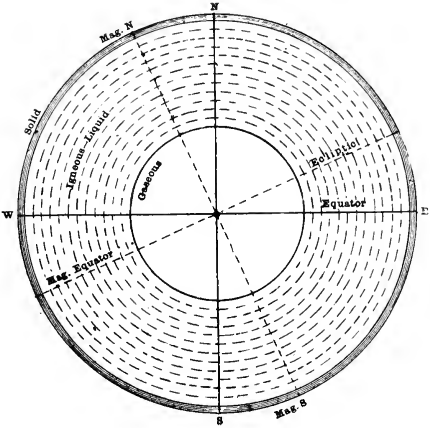
Plate XVI. Magnetarium, for demonstrating the differential rotation of the internal parts of the earth and the resultant phenomena of terrestrial magnetism on its surface.



HALLEY. 1692.



WILDE. 1890.



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XI. On a Modification of Rose's Method of Separating Cobalt and Nickel.

By R. L. Taylor, F.C.S.

Read February 18th. Received March 4th, 1902.

Numerous methods have been proposed for the purpose of separating cobalt and nickel when in solution together. The two metals, however, are so much alike in their general properties, that very few methods appear to give satisfactory results, and those few are as a rule troublesome and tedious.

The method which I have described as "Rose's method" was proposed by him over 50 years ago (*Pogg. Annal., Bd.* 71, *p.* 545), and a translation of Rose's paper, by T. H. Henry, appeared in the *Chemical Gazette* for 1847, page 362, accompanied by some remarks on the method by the translator. The process, while fairly satisfactory, was very tedious and troublesome, and, probably for that reason, it appears to have gone out of use. It is described in Gmelin's *Handbook* and in various editions of Fresenius' *Quantitative Analysis*, but very few modern text-books even mention the reaction (which is interesting and important) upon which the method depends. For example, it is not referred to in Roscoe and Schorlemmer's *Treatise on Chemistry*, and there is no mention of it in the newer Watts' *Dictionary of Chemistry*.

Rose's method depends upon the fact that cobalt is precipitated as the black sesquioxide by various insoluble carbonates (such as those of barium, strontium and

calcium) in presence of free chlorine or bromine, and that nickel is not so precipitated. The following equation practically represents what takes place in the case of cobalt:—

$$2CoCl_2 + 3BaCO_3 + Cl_2 = Co_2O_3 + 3BaCl_2 + 3CO_2.$$

It is very probable, however, that the cobalt is converted from a cobaltous to a cobaltic salt before it is precipitated by the carbonate.

According to his original description of the process, Rose passed a stream of chlorine through a somewhat dilute solution of the chlorides of the two metals, containing a considerable excess of hydrochloric acid, for several hours. He then added excess of barium carbonate and allowed to stand, with frequent agitation, for from 12 to 18 hours. By the end of that time the cobalt was all converted into sesquioxide and the nickel remained in solution and could be filtered off. In his remarks on Rose's method (referred to above) Henry suggested the use of bromine instead of chlorine. In a subsequent letter (*Chemical Gazette*, 1855, p. 237), Henry stated that he had, by keeping the temperature at 120° F., succeeded in reducing the time required to a few hours. He considered that the results, however, were not so good as those obtained by Liebig's method of separation by means of potassium cyanide.

Induced principally by a desire to find a better method than those usually employed for the qualitative separation and detection of nickel in presence of cobalt, I have recently made some experiments on the action of barium and calcium carbonate on solutions of the two metals, in presence of chlorine and bromine. As the result of these experiments, I find that the method of Rose can be considerably shortened, with the result also of making it much more accurate.

The mistake which both Rose and Henry made was in the use of free hydrochloric acid before the addition of chlorine (or bromine) and the carbonate. Rose mentions having tried a neutral solution, but with unsatisfactory results. On the other hand, I find that if there is *no* free acid present, barium or calcium carbonate, in presence of chlorine or bromine, will precipitate cobalt completely in three or four minutes. Perhaps barium carbonate acts a little more rapidly than calcium carbonate, but, in a great many experiments I have made, neither of them has ever failed to precipitate the cobalt in five minutes.

With a neutral solution of nickel, on the other hand, I have never found any precipitation of the black oxide within an hour. After a longer time, a black deposit begins to form on the side of the vessel at the edge of the liquid, where the air has access to it. If air is excluded nickel scarcely appears to be precipitated at all. I have had solutions of nickel in presence of both barium and calcium carbonate and bromine water in stoppered bottles for some weeks without any appearance of precipitation of the black oxide. When the liquid is heated to a temperature of 70° or 80° C., the nickel is rapidly precipitated as the black sesquioxide.

If, however, much free acid is present when the carbonate and bromine water are added, as was always the case in following Rose's original method, the precipitation of the cobalt is very considerably retarded. It may take hours, and sometimes does not even begin for over half-an-hour. This explains why Rose found it necessary to allow his solutions to stand so many hours.

The retarding effect of the free acid is rather surprising, because all free acid naturally becomes neutralised by the carbonate employed, which must always be in

excess. My first impression was that the soluble barium or calcium salt formed when the acid is neutralised by the carbonate must be the cause of the retardation, but experiment showed that it was not. The cause of the retardation is simply free carbonic acid. If, after adding the carbonate to a solution of cobalt containing free acid, the liquid is boiled (to expel the carbon dioxide) and cooled again before adding the bromine water, there is no retardation. Also, if carbon dioxide is bubbled through a *neutral* solution of cobalt, or if such a solution is mixed with ordinary soda-water, on adding the carbonate and bromine water there is a retardation of the precipitation of the cobalt similar to that observed when free acid is present at the outset.

This curious retarding action of free carbonic acid appears additionally strange when it is borne in mind that carbon dioxide is one of the products of the reaction itself, and that immediately the reaction begins there must be free carbonic acid present in the liquid. Plainly, the retarding action of the free carbonic acid is very slight unless there is a considerable amount of it in proportion to the water, and in dilute solutions the amount never becomes sufficient. In *strong* neutral solutions the carbonic acid produced during the reaction has its effect, and the precipitation of the cobalt takes much longer. At present I am unable to suggest any reason why free carbonic acid should exert this curious retarding effect.*

With a dilute solution which is approximately neutral the process of separation works rapidly and well. I have tested it quantitatively with most satisfactory results. The

* It is well known that manganese is precipitated by barium or calcium carbonate under the same circumstances as cobalt, and I find that free carbonic acid acts exactly as it does with cobalt,—the precipitation of the manganese is very considerably retarded.

materials I used were the crystallised chlorides of the two metals, each guaranteed by the makers as free from the other.

A solution of chloride of nickel was prepared, of no definite strength, and the amount of nickel in it was determined by electrolytic deposition, from an ammoniacal solution, on a weighed platinum basin,—a process of estimating nickel which appears to be most satisfactory. In this way, in two separate experiments 50 c.c. of the solution, gave 0·1350 and 0·1355 gramme of metallic nickel respectively. In two further experiments, 50 c.c. of the same solution were mixed, in each case, with an indefinite amount of a solution of cobalt. The two metals were then separated by adding excess of precipitated barium carbonate, made into a paste with water, and bromine water. Ten minutes were allowed for the precipitation of the cobalt. After filtering and washing, the barium was removed from the filtrate by precipitation with sulphuric acid, the liquid evaporated to a small bulk, and the nickel determined by electrolytic deposition. The two experiments gave respectively 0·1345 and 0·1347 gramme of nickel.

In a similar way a solution of chloride of cobalt was prepared, and the amount of cobalt in it determined by electrolytic deposition from a solution of the double oxalate of cobalt and ammonium, this being one of the solutions of cobalt which is said to give the best results. But, in my hands at any rate, the process of electrolytic deposition is not so satisfactory with cobalt as with nickel. The deposited metal is not so clean, and it is difficult to know when the process is complete. Thus, in one experiment 50 c.c. of the solution of cobalt, electrolysed for 5 hours (when the deposition seemed to be complete), gave 0·1517 gramme of metallic cobalt. In another experiment,

when the electrolysis was carried on through the night (altogether about 17 hours) 50 c.c. gave 0·1537 gramme of cobalt. Possibly the larger amount represents the true strength of the solution.

Mixtures were next made of 50 c.c. of each of the two solutions, the separation effected as before, and both the cobalt and nickel determined electrolytically. In one experiment, where the electrolysis of the cobalt solution was allowed to proceed throughout the night, 0·1542 gramme of cobalt and 0·1352 gramme of nickel were obtained. In another, where the cobalt solution was electrolysed for seven hours, the numbers were 0·1532 and 0·1347 respectively.

In addition to the above results obtained by myself, some experiments on this method of separation have been made by Mr. David Segaller, A.R.C.S., Dublin, with equally satisfactory results.

The above results are very much better than those quoted by Rose and Henry for the original method. This may be due to the fact that my materials were probably purer than any they were able to obtain. The results demonstrate quite satisfactorily that by this method the separation of cobalt and nickel is not only rapid, but complete.

The process not only acts well quantitatively, but I recommend it very strongly for the separation and detection of cobalt and nickel in the ordinary process of qualitative analysis. The mixed sulphides of cobalt and nickel are dissolved in the usual way in dilute hydrochloric acid with the aid of a crystal of potassium chlorate. The liquid is then boiled down just to dryness in order to expel the free acid. The residue is taken up with water, and precipitated barium or calcium carbonate and

bromine water added.* It is now allowed to stand for five minutes, with frequent shaking. If cobalt is present, a black precipitate very soon appears. At the end of five minutes the liquid is filtered and the filtrate tested for nickel by the addition of a drop or two of ammonia and ammonium sulphide. The presence of cobalt in the precipitate may be confirmed by the borax bead test. In this way nickel may be detected even when present in very small quantity, and when the cobalt is largely in excess.

Instead of boiling off the free acid, it may be neutralised with sodium or potassium hydrate before adding the carbonate and bromine water; or the carbonate of barium or calcium may be added in excess to the acid liquid, and then the liquid boiled for a short time to expel the free carbon dioxide. It must then be cooled to the ordinary temperature before adding the bromine water.

The carbonates of barium, strontium and calcium are not the only ones which act in the manner described; the carbonates of magnesium and zinc apparently act in the same way. Thomas Moore (*Chem. News, Vol.* 82 (1900), *p.* 73), describes the use of zinc oxide and bromine water for the purpose of estimating small quantities of cobalt in presence of nickel. Mr. Moore finds that those reagents precipitate cobalt as sesquioxide, but not nickel, even on boiling. He insists that bromine *must* be used, and not chlorine. I have tried the experiment, and fail to find any difference at all between the action of chlorine and bromine.

* Barium and calcium carbonates appear to act equally well. The dry substances may be employed. Barium carbonate is preferable if the subsequent removal of the added metal is desired.

CENTRAL SCHOOL,
MANCHESTER.

Manchester Memoirs, Vol. xlvi. (1902), *No.* **12**.

XII. The Chatham Islands: a Study in Biology.

A Lecture delivered, by invitation of the Council, on March 4th, 1902.

By ARTHUR DENDY, D.Sc.,

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Ever since the publication of Wallace's famous work on "Island Life," the study of insular faunas and floras has attracted special attention from biologists, and it has been clearly recognised that the fundamental laws which govern the geographical distribution of plants and animals receive their best illustration in such rigidly circumscribed areas as may be included under the term 'Island,' where the number of species to be studied is less overwhelming than on continents, and where the geographical isolation gives full play to the powers of variation.

The time-honoured classification of islands into two great groups—continental and oceanic—is undoubtedly extremely useful, but, like all other systems of classification, it occasionally breaks down. New Zealand, for example, is thoroughly oceanic in the character of its fauna—in the absence of indigenous mammalia (with the exception of rats and bats), the total absence of snakes and the almost complete absence of amphibia, and no less in the extremely high degree of peculiarity amongst those animals and plants which it does possess; but, on the other hand, its geological characters are continental—it is not entirely of volcanic formation, but contains sedimentary rocks dating back to palæozoic times, while

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the configuration of the sea-bed affords us grounds for believing that the New Zealand of to-day is but a fragment of a much larger land area which existed in former times, and which was perhaps nearly, if not quite, connected in the north with northern Australia, and perhaps even, at some extremely remote period, with the continent of Asia.

It is not, however, of the main islands of New Zealand that I wish to speak to-night, but of a small outlying group situated some 400 miles to the east, and almost in the same latitude as Christchurch. Both in their physiography and in their fauna and flora the Chatham Islands stand in much the same relation to New Zealand as New Zealand does to North Eastern Australia, and the problem of tracing the origin of their existing plants and animals is one of the most fascinating which a naturalist could desire. To the ethnologist also they offer almost equal opportunities for research, for, though the once flourishing Moriori race is now on the extreme verge of extinction, they have left behind a great deal of evidence as to their characters, manners, and customs.

Our knowledge of these remote islands is still very imperfect, and I can only attempt to place before you to-night some of the facts which came under my notice in connection with a short visit in January of last year—in the Southern summer.

To reach the Chatham Islands from New Zealand is in itself an arduous task. Two and a half days bucketing about on a rough sea in a small steamboat, with perhaps a thousand live sheep as travelling companions, is enough to deter most people from making the attempt, and, as a consequence, the island is not often visited except by those who have business to transact. Moreover, the steamboat service is hardly what would be considered up

to date even in New Zealand. Excepting during the wool season, when the only boat in the service runs backwards and forwards pretty frequently, communication with New Zealand takes place only once in every two months, so that there are few more isolated civilized communities in His Majesty's empire than the little group of European settlers on these islands.

Chatham Island itself is only about 30 miles in greatest length; Pitt Island, separated by a wide strait and lying to the south, is very much smaller, and in addition to these two there are only a few small outlying rocks.

The group is of volcanic origin and the configuration of the main island is very peculiar. Nowhere exceeding 1,000 feet in height, the interior is chiefly occupied by an extensive lagoon known as "Te Wanga." The western part of the island is made up partly of low hills of basalt; on the east the lagoon is separated from the sea only by low sand dunes. On the north and west also there are long sandy beaches and extensive sand-hills. Here and there are low sandstone cliffs on the sea shore, and near Cape Young there is a deposit of tertiary limestone containing enormous quantities of beautifully preserved fossils, chiefly pectens and brachiopods. A considerable portion of the surface of the island is occupied by flat boggy country clothed with a characteristic moorland vegetation, and sometimes covered by a great depth of peat.

In addition to the great lagoon, which is said to be very deep, and which probably marks the crater of an old volcano, there are several smaller lakes. The lagoon is fed by several small streams, and discharges its surplus water into the sea through a channel which has to be artificially maintained in order to keep the water from flooding the low-lying pasture lands about its shores.

As regards climate the islanders have little to complain of; the rainfall is plentiful without being excessive, and the cloudiness of the atmosphere contrasts favourably with the too brilliant sunshine of many parts of Australasia. The absence of severe frost permits the growth of plants which will not flourish in the southern parts of New Zealand, and, were it not for the somewhat severe winds, the vegetation would be still more luxuriant.

FLORA.

The total number of species of flowering plants and ferns indigenous to the group is probably somewhat under two hundred; the lower plants are as yet very imperfectly known. For purposes of description the flora may be conveniently divided between Forest, Moorland, and Sea-coast.

THE FOREST FLORA.—A considerable portion of the island, especially in the south-west, is still covered with dense forest. This forest was formerly much more extensive than at the present day, but it has been largely cleared away with a view to extending the pastures. In some places this destruction of the natural wind-break has resulted in much damage from the drifting in of the sand, which is now being checked by the planting of Marram grass. There are no really large trees, and the average height of the forest is perhaps only about 20 feet, while the level of the tree tops appears to be very evenly maintained by the severity of the wind; where undisturbed, there is still a luxuriant undergrowth of shrubs and ferns. There are, I believe, no indigenous deciduous trees or shrubs, and the evergreen character of the forest assists in keeping out the wind and promoting the growth of ferns.

The principal forest trees are as follows:—

Corynocarpus lævigatus (nat. ord. Anacardiaceæ), the 'Karaka' or 'Kopi' of the natives, a tree which also flourishes in those parts of New Zealand where there is no frost, especially near the coast. This is a handsome tree with a thick trunk, smooth bark, and glossy leaves, something like a laurel. The leaves are greedily eaten by cattle, so that it is really a valuable fodder plant, while the fruit, resembling a yellow plum, formed one of the chief articles of food amongst the Morioris. The tree is allied to the Mango and the genus is peculiar to New Zealand and the adjacent islands.

Olearia traversii (nat. ord. Compositæ), the "Ake ake" of the Maoris, is a handsome tree peculiar to the Chathams. Its flowers and fruit are inconspicuous, but its robust growth and dense foliage make it very valuable as a shelter plant.

Senecio huntii (nat. ord. Compositæ), the "Rautini" of the natives, a magnificent flowering tree peculiar to the Chathams. Though belonging to the same genus as the European groundsel, it attains a height of perhaps 20 feet, with a thick woody trunk, and large bunches of beautiful, bright yellow flowers.

Coprosma sp. (nat. ord. Rubiaceæ), a species of Stinkwood which attains a large size, and is perhaps distinct from its nearest New Zealand relative and, if so, peculiar to the Chathams. The genus is very characteristic of New Zealand.

Myrsine chathamica (nat. ord. Myrsineæ, near Primulaceæ). Peculiar to the Chathams, but again belonging to a characteristic New Zealand genus.

Piper excelsa (nat. ord. Piperaceæ), the "Kawa Kawa" of the inhabitants, sometimes used for the preparation of a kind of beer ; a species also abundant in the warmer parts of New Zealand. One of the pepper-trees.

Veronica sp. (nat. ord. Scrophularineæ). Perhaps the largest Veronica in the world, forming a tree 20 feet high, with a woody trunk a foot in diameter. Almost certainly distinct from any New Zealand species, and, if so, peculiar to the Chathams.

Korokia sp. (nat. ord. Corneæ). Probably specifically distinct from, though closely related to, the New Zealand *C. buddleioides.*

Myoporum lætum (nat. ord. Myoporineæ, near Verbenaceæ); the 'Ngaio' of the Maoris. A handsome tree with glossy gland-dotted leaves and pretty purple-spotted flowers. Also common in the warmer parts of New Zealand.

Dracophyllum scoparium (nat. ord. Epacrideæ, the southern representatives of the European heaths). A curious arborescent Epacrid of a genus very characteristic of New Zealand, where the same species also occurs. Its scraggy growth and narrow grass-like leaves give it a very remarkable appearance.

Pseudopanax sp. (nat. ord. Araliaceæ). A remarkable plant closely allied to the common New Zealand "lancewood" but probably distinct, the narrow sword-shaped leaves of the young tree apparently never drooping as in the latter.

Sophora sp. (nat. ord. Leguminosæ). Probably identical with the common New Zealand "Kowhai," a handsome tree with pinnate leaves and large yellow flowers shaped like a bird's beak.

Hymenanthera chathamica (nat. ord. Violaceæ), peculiar to the Chathams, but belonging to a characteristic New Zealand genus.

Plagianthus sp. (nat. ord. Malvaceæ), one of the "Ribbon-woods," apparently differing slightly from the common New Zealand species (*P. betulinus*).

Amongst the undergrowth, which, where undisturbed, may be very dense, we may notice the common "Tutu" of the New Zealanders (*Coriaria ruscifolia*), a plant which has often proved very destructive to cattle from its poisonous properties. *Rhipogonum scandens* is a tall liane of the natural order Smilaceæ, forming festoons over the trees, with handsome red berries and rope-like stems, which are said to have been used by the Morioris for binding corpses to the trees; it is also common in New Zealand. *Mühlenbeckia australis* (nat. ord. Polygoneæ) is another common New Zealand liane. The Chatham island palm (*Rhopalostylis baueri*) which grows luxuriantly in the shade of the forest, is quite distinct from, though allied to, the common "Nikau" of the warmer parts of New Zealand; with its tall stem surmounted by a tuft of graceful feathery leaves, it forms a singularly beautiful feature of the vegetation. Tall tree ferns also add greatly to the charm of the forest, and it is sad to see them ruthlessly cut down and used for making fences, &c. As in New Zealand, there is also a wealth of smaller ferns. A charming little epiphytic orchid (*Earina mucronata*) may complete our list of the more important representatives of the forest flora.

THE MOORLAND VEGETATION consists largely of the common bracken fern, whose starchy rhizomes formed an important article of diet amongst the Maoris in New Zealand and probably also amongst the Morioris. Two Epacrids, representing the northern heaths, cover a large area of ground. The one is a species of *Cyathodes*, probably endemic, forming small bushes with a profusion of large pink or white berries, and the other a *Dracophyllum* of dwarf habit, with narrow grass-like leaves. The most beautiful of the moorland plants is, however, a shrubby

composite, *Olearia semidentata*, with large purple flowers resembling the Michaelmas daisies of our gardens. This species is peculiar to Chatham Island, but closely related to a species found in S.-W. New Zealand; it occurs in large patches on the open moors.

The beautiful "Toi-toi" grass (*Arundo conspicua*), with its tall feathery plumes, may also be mentioned as a moorland plant, and is likewise a conspicuous feature in the New Zealand landscape. The remarkable genus *Aciphylla* (nat. ord. Umbelliferæ), so characteristic of New Zealand, is represented by at least one species which may be endemic; and amongst the smaller herbs may be mentioned the genera *Acæna*, *Epilobium*, *Lobelia*, *Libertia*, and the orchids *Pterostylis* and *Chiloglottis*.

THE COAST FLORA.—It is, of course, impossible to draw anything like a sharp line of distinction between the vegetation of the sea-coast and that of the forest and moorland; indeed, the entire flora of Chatham Island is in the main of a coastal character, and the forest itself may come close down to the sea. Nevertheless there are certain plants which are more or less distinctively shore-dwellers. Amongst these may be included a remarkably fine *Olearia* which grows on Pitt Island, forming a large shrub with very handsome purple flowers. This plant is closely related to *Olearia chathamica*, another endemic species of the larger island. A small *Coprosma*, known as the "mutton-bird plant," grows around the entrances to the mutton-bird's burrows. *Veronica chathamica*, an endemic species, trails over the low cliffs, and is a very handome plant. *Geranium traversii* is a pretty little pink or white-flowered plant, also peculiar to these islands. *Mesembryanthemum australe* and *Sonchus oleraceus* are well-known New Zealand plants. *Leucopogon richei*, one of the Epacrids,

is remarkable for being an Australian species found on Chatham Island, but not in New Zealand. One of the native flaxes, belonging to a very remarkable Liliaceous genus (*Phormium*), highly characteristic of New Zealand, may be found growing on the rocks, and so also may *Pimelea arenaria.* The common *Desmoschœnus spiralis* (Cyperaceæ) of the New Zealand coast, occurs on sandy places, but does not appear to have been very successful in holding the sand together, a task which is now being performed by the introduced Marram grass already referred to.

By far the most remarkable of the coastal plants, however, is the so-called Chatham Island Lily, *Myosotidium nobile*, really a gigantic forget-me-not, which luxuriates in the sand a short way above high-water mark. Its large, glossy and to some extent succulent leaves, and its general habit, remind one forcibly of young rhubarb, while its bunches of beautiful blue flowers at once reveal its true affinity, though the flowers are very much larger than in ordinary forget-me-nots. This very interesting plant has a remarkable distribution, being found only on the Chatham Islands and the Snares (near Stewart Island, south of New Zealand). Unfortunately it has been already nearly exterminated by stock on Chatham Island, but it will doubtless be preserved as a garden plant, being very readily raised from seed.

Even such a hasty survey of the Flora as we have been able to make, shews us that it is essentially a detached fragment of the Flora of New Zealand. It exhibits, however, when compared with that of New Zealand, many striking deficiencies, such as the entire absence of Conifers, Beeches, Fuchsias, most if not all of the Myrtaceæ, the Carmichaelias and the "Cabbage Trees" (*Cordyline*), while at the same time it possesses a large proportion of peculiar

species and varieties, differing more or less from nearly related forms in New Zealand. One genus (*Myosotidium*) is found nowhere else but on the Snares, though the allied *Myosotis* occurs both in New Zealand and Chatham Island. The shrubby and arborescent Compositæ rival even those of New Zealand, and *Senecio huntii* is perhaps the finest and most remarkable member of its genus.

Our knowledge of the Flora of the Chatham Islands is, however, still far from perfect. We owe most of our systematic information to Travers, Mueller and Hooker, while Diels has treated the subject philosophically in his interesting memoir on the Biology of the New Zealand Flora, of which I have made free use in the preparation of this lecture; but we may hope that our knowledge will shortly be placed upon a much more satisfactory footing by the painstaking researches of the well-known New Zealand botanist Mr. L. Cockayne, to whom I am indebted for many of the photographs exhibited to-night.

FAUNA.

The Chatham Islands, of course, share with New Zealand the absence of terrestrial mammalia so characteristic of oceanic islands, and it is perhaps hardly necessary to point out that this deficiency in the fauna is due to the fact that these islands have been so widely and so long separated from any continental area, that no animals not possessed of the powers of flight, or capable in some way or other of traversing large stretches of open ocean, can ever find their way to such remote regions.

With birds, on the contrary, our islands are well supplied, but here also we find a feature which is very characteristic of oceanic islands, and which is even more conspicuous in New Zealand. I refer, of course, to the occurrence of birds which have more or less completely lost the power of

flight. This character stands in direct correlation with the absence of predacious mammals. The power of flight being no longer required as a means of escape from their enemies, some of the birds have given up expending their energies in that direction, living and feeding on or near the ground. The wings of these birds, offering no special advantages to their possessors, have not been preserved by natural selection, and have to a greater or less extent degenerated. The disappearance of the wings appears to have been complete in the gigantic New Zealand Moas, now extinct, and has been carried to varying degrees in the Kiwis (*Apteryx*), rails (*Notornis, Ocydromus*) and great ground parrot or Kakapo (*Stringops*). Now that numerous predacious mammals, such as dogs, cats, weasels, &c., have been introduced into these islands by the agency of man, the flightless birds are paying with their lives for their long immunity from the struggle for existence, and will, unfortunately, soon become extinct except where specially protected.

The avian fauna of the Chatham Islands is, like the flora, characterized by a large proportion of peculiar forms and by striking deficiencies as compared with New Zealand, though the general characters are distinctly Novo-Zealandian. The flightless rails are represented by the diminutive *Cabalus modestus* and *Nesolimnas dieffenbachii.* The distribution and extinction of *Cabalus modestus* are extremely instructive; found only on one or two rocky islets in the neighbourhood of Pitt Island, it affords one of the best examples of a restricted area of distribution, while its extermination on Mangare, its best known habitat, seems to have been largely due to the introduction of cats.

The kiwis and kakapo of New Zealand appear never to have made their way to Chatham Island, where the

most important existing land bird is, perhaps, the pigeon (*Carpophaga chathamensis*), and even this is specifically distinct from the New Zealand form. This bird appears to have formed part of the abundant food supply of the Morioris.

A very remarkable feature of Chatham Island is the enormous abundance of birds' bones imbedded in the soft or indurated sand dunes and cliffs along the sea shore, where the conditions appear to be in some unknown manner especially favourable to the preservation of such remains. Amongst these are a flightless rail (*Diaphorapteryx hawkinsi*), a coot (*Palæolimnas chathamensis*), a swamp hen (*Porphyrio chathamensis*), a crow (*Corvus moriorum*), and a swan (*Cygnus sumnerensis*). These are all or nearly all extinct at the present day, and all but the swan, which has been found also in New Zealand, are, so far as I know, peculiar to the Chathams. Like their existing representatives, the kiwis, the moas appear never to have found their way to these islands at all.

With regard to their reptilian fauna the Chathams offer a striking contrast to the main islands of New Zealand, for whereas we find on the latter a considerable number of lizards (to say nothing of the remarkable Tuatara, now confined to certain small islets near the mainland), the only reptile found on the Chathams is a solitary species of lizard lately described by Mr. Boulenger under the name *Lygosoma dendyi*, and most nearly allied to *L. moko* of New Zealand. It is a remarkable fact that, though apparently common on Pitt Island, this lizard is not known to occur on Chatham Island proper, its geographical range being perhaps as narrowly restricted as that of *Cabalus modestus*.

As might be expected the amphibia are quite unrepresented on the Chathams, for even in New Zealand

proper there is only a single species of frog, confined to a small area in the north and now very rare.

Of fresh-water fish I have no complete list, but it is remarkable that there are in the Canterbury Museum at Christchurch no less than four species of *Galaxias* said to come from this small group.

Our knowledge of the invertebrate fauna is still no doubt very incomplete, and I have not sufficient data at hand to enable me to attempt a detailed comparison with New Zealand. The general characteristics of the invertebrate fauna are, however, certainly very similar in the two cases, and there can be little doubt that many of the species are identical. I will quote only one example, which is of great interest, because it clearly shows how small animals, such as worms, insects, or mollusca, may reach the islands from New Zealand, even at the present day, in spite of the wide intervening stretch of ocean.

Being myself specially interested in the Land Planarians, a group of small, soft-bodied worms, very abundant both in New Zealand and Australia, I devoted some attention to these animals while on the Chathams. One species I found very abundant in or under rotten logs ; it was very easily recognised by a peculiar and quite distinctive arrangement of colour-markings, and I found it to be identical with a species, *Geoplana exulans*, which I had previously received only from the North Island of New Zealand. Now there can be no doubt that there is a well-marked ocean-current running from the north-east of New Zealand to Chatham Island. I myself found a piece of pumice stone on the shore which must have come from the North Island of New Zealand, and I was informed, on excellent authority, that kauri logs from the Auckland district, with the mill-brand on them, are frequently stranded on the Chathams. New Zealand government

telegraph posts, and a buoy from Wellington, have been conveyed to these islands in the same way. I also learned that though there is no totara (*Podocarpus totara*, a common New Zealand forest pine) growing on the island, yet good-sized totara trees, apparently drift timber, are found buried, sometimes beneath peat, near the sea, at several localities.

There can, I think, be little question that *Geoplana exulans*, and perhaps many other small invertebrate animals, were introduced to the Chathams from New Zealand by means of floating timber in the manner thus clearly indicated.

ORIGIN OF THE FAUNA AND FLORA.

All who have studied the question are agreed that the fauna and flora of the Chatham Islands are simply isolated detachments of those of New Zealand, although the striking differences which we have had occasion to notice imply a long period of isolation. This view of the case requires us to believe that the islands, though now separated by 400 miles of open ocean, were at one time either actually connected with the New Zealand mainland, or, at any rate, much more nearly so than at the present day, a belief which is strongly supported by the fact that the sea between New Zealand and the Chathams is comparatively shallow, only from 500 to 1,000 metres in depth, while further to the east it sinks at once to 4,500 metres (Diels). In the upper Pliocene period it is probable that the area of New Zealand was greatly extended so as to embrace, for example, Chatham Island in the east, Lord Howe Island in the north-west, Auckland and Campbell Islands in the south. The immense area of land thus formed has been styled by Diels "Great New Zealand," and corresponds more or less to Wallace's

New Zealand Sub-region. This condition is supposed to have lasted on into Pleistocene times, and to have been followed by another depression, which left the islands very much in their present condition.

The former land connection thus roughly sketched out, together with the ocean current already referred to, would be quite sufficient to account for the great resemblances between the fauna and flora of the Chatham Islands and those of New Zealand proper. Indeed, it is the differences rather than the resemblances which require explanation, and there appear to be at least three good reasons why such differences should exist.

1. The climate of the Chatham Islands is only suitable for certain portions of the New Zealand flora. It is not suitable for xerophilous or desert-loving types such as *Discaria* and the New Zealand brooms (*Carmichaelia, Notospartium*), nor is it suitable for the alpine and subalpine types which form such a characteristic feature of the New Zealand vegetation.

2. In the days of "Great New Zealand" the physical condition of the land must have been such as to bring about the existence of an enormous desert tract between the Chathams and New Zealand proper. Even in the New Zealand of the present day the lofty range of the Southern Alps cuts off most of the rainfall from the Canterbury Plains, and this condition of drought must have been greatly aggravated in upper Pliocene times, when the Southern Alps were very much higher than at the present time and the interior of the desert was much further removed from the sea. Thus the more elevated area of the Chathams, though connected indeed with New Zealand, was at the same time in large measure separated by a desert tract which must have formed a very serious barrier to the migration both of plants and animals. A

number of temperate types, however, appear to have reached the Chathams along the coast from the south. Such are the gigantic forget-me-not (*Myosotidium*), whose occurrence elsewhere only on the Snares, south of New Zealand, is extremely suggestive in this respect, and the large-flowered Olearias, which are closely allied to species found in the south-west of New Zealand. Probably other types, shewing subtropical characters, spread southwards along the coast from the north, such, for example, as the Karaka or Kopi tree (*Corynocarpus*), which is essentially a northern form. Thus the vegetation of the Chatham Islands is largely of a coastal type, and the absence of such characteristic elements of the New Zealand flora as, for example, the great forest pines and the evergreen beeches, may be accounted for by the existence of climatic barriers which they have never been able to surmount. The same explanation may perhaps be applied to the absence of the moas and kiwis.

3. Sufficient time has elapsed since the islands again became disconnected from the mainland to permit of the origin of many new species, or at any rate varieties. This, of course, has been rendered possible by the geographical isolation of those plants and animals which had managed to find their way to this remote region. Variation is constantly going on amongst most species, and it is now well known that when any section of a species is isolated and prevented from intercrossing with the remainder of that species, new varieties (and ultimately species) are likely to arise; while in the absence of some form of isolation the swamping effects of intercrossing are likely to preserve uniformity of character amongst the individuals concerned. The importance of isolation in the development of new species, ably demonstrated by such writers as Gulick and Romanes, could hardly be better illustrated than in the fauna and flora of the Chatham Islands.

Ethnology.*

Although logically, no doubt, the human population should have been dealt with as part of the fauna of the Islands, it is more convenient to follow the usual custom and treat of this portion of our subject under a separate heading.

There are, perhaps, few more striking examples of the extermination of a primitive native race than that afforded by the rapid disappearance of the Moriori inhabitants of the Chatham Islands during the nineteeth century. At the time of my visit, in January, 1901, there were only about a dozen pure-blooded individuals left; some of these were of great age, while the youngest was a lad of about 16. Under these circumstances it must be considered extremely fortunate that any reliable record of this interesting people has been preserved, and that such is the case is due largely to the energy and enthusiasm of Mr. Alexander Shand, who for more than thirty years has lived amongst the Morioris, and has made a special study not only of that race, but also of their Maori conquerors. Mr. Shand, whose acquaintance I first had the pleasure of making at Whangamarino, his home on the Island, has published a series of extremely valuable papers on the subject in the journal of the Polynesian Society, from which, as well as from my personal intercourse with the author, much of my information has been derived. I must also refer in this connection to the interesting papers by Mr. Gilbert Mair and Mr. Travers in the *Transactions and Proceedings of the New Zealand Institute.*

* This portion of the lecture has already been communicated, with little difference beyond the addition of illustrations, to the Philosophical Institute of Canterbury (see *Transactions and Proceedings of the New Zealand Institute* for 1901); it was also made use of for an article in the Christchurch "Press" (New Zealand), December 11th, 1901, on the extinction of the Moriori.

It appears from their language, customs and traditions, as well as from their physical characteristics, that the Morioris are closely related to the New Zealand Maoris, from whom, indeed, none but an expert could distinguish them, though Mr. Shand considers that they are, if anything, a shade darker and perhaps even more of a Jewish cast. Their ignorance of the art of tattooing, and their very inferior artistic faculties in general, however, point to a very remote separation of the two races.

Like the Maoris they trace their origin to an unknown fatherland called Hawaiki, from which they must have emigrated to Chatham Island in canoes. In their new home they appear to have found the conditions of life remarkably easy, indeed, as the sequel shews, fatally so. With an abundant natural food supply of fruit, fish, &c., and with no enemies to contend with, they multiplied until the islands were thickly populated, while at the same time they probably became lazy and effeminate.

The discovery of the island, which they themselves called Rĕkŏhu, by the brig "Chatham" in 1790, may be said to have sealed the fate of the unfortunate Moriori, though it is doubtful whether any serious injury ensued until the advent of the whaling and sealing vessels in 1828. These vessels took many undesirable visitors to the island, and probably introduced a disease which soon played havoc with the native race. On board some of the ships were Maoris from New Zealand, who on their return painted such a glowing picture of the land of plenty, that a large number of their fellow-countrymen determined to emigrate to Chatham Island, or as they called it, Wharekauri, *en masse.*

In order to effect this purpose they took possession of the brig "Rodney" at Port Nicholson, in New Zealand, about the beginning of November, 1835. They are said to

have seized the crew and compelled the captain, by fair means or foul, to take them to the island of their desire, whither, in two trips, about 900 Maoris were transported, and let loose upon the unfortunate inhabitants, already decimated by some virulent disease. Those who are fond of extolling the virtues of the Maori race would do well to study impartially the history of their occupation of Chatham Island. At the time of the invasion the Morioris are supposed to have numbered some two thousand, and had they attacked the new-comers on their first arrival, when too weak from the results of the voyage to offer effective resistance, they might have exterminated them with little trouble and prolonged for an indefinite period the life of their own race. Unfortunately for themselves, however, they had lost the art of self-defence. Owing to the absence of competition they had, in this respect at any rate, undergone degeneration. Killing was actually forbidden by their laws and peace had reigned too long and too securely to give place at once to war when the emergency arose. Just as the wingless birds have more or less completely disappeared before the advance of introduced carnivores, so the Morioris, their happy isolation once broken, fell an easy prey to the more virile New Zealanders. The latter proceeded to parcel out the conquered country amongst themselves, claiming not only the land but also the inhabitants thereof, who were speedily reduced to the condition of slaves, and put to hard labour for their brutal masters.

Mr. Shand tells us how "Te Wharekura, of Te Raki, "with his *hapu*, killed and roasted 50 Morioris, in one "oven,—it might have been more than one,—for no reason "whatever that could be assigned," while at Waitangi one Tikaokao and others massacred men, women and children of the conquered race, and laid them out on the

sandy beach touching one another, some of the women being left to die with stakes thrust into them. It may be of interest to compare with this ghastly history the brief remarks on the Moriori race made by the Bishop of New Zealand, who visited Chatham Island in 1848. The following quotation is taken from a work entitled, "Church in the Colonies, No. XX., New Zealand, Part V. "A Journal of the Bishop's Visitation tour through his "diocese, including a visit to the Chatham Islands, in the "year 1848." (London: Printed for the Society for the Propagation of the Gospel, and sold by the Society for promoting Christian Knowledge, 1851).

THE BISHOP OF NEW ZEALAND'S ACCOUNT OF THE MORIORI RACE (1848).

"In appearance they are not very different from the New Zealanders; and their language at the time of the invasion (about ten years ago) was perfectly intelligible to the Ngatiawa tribe, who usurped their territory. Their name, as spoken by themselves, is Tangata Maori*ori*, differing from the name of the New Zealand people only in the reduplication of the last syllables; but the conquerors have given them the title of "Paraiwhara," the meaning of which I could not ascertain. Their number at the time of my visit, by a careful census which I took of the names of men, women, and children, was 268; but the very small number of children, and the unmarried state in which they seemed for the most part to be living, would lead me to fear that they were rapidly decreasing. The relation in which they stand to the New Zealanders is not satisfactory. They have been reduced to the condition of serfs, and are obliged to obey the orders of every little child of the invading race. The common expression of "Ngare Paraiwhara," send a

Paraiwhara, shows that a "fagging" system has been established, more injurious, perhaps, to the masters than to the servants, as there is no appearance of harshness or severity, but a great decrease of personal activity in the dominant race. A long residence on the island would be necessary to do away entirely with this evil; but I did what I could in a short visit, by paying personal attention to the poor Paraiwhara, and explaining how they were descended from the elder branch of the family of Noah, by which they obtained the name of the "tuakana o te Pihopa" (the elder brother of the Bishop). They are a cheerful and willing people; and, like many persons in a subordinate station, more obliging than their masters. Amusing stories are told of the first invasion of the island; at which time the chief food of the Paraiwhara was the supply of eels from the numerous lakes which cover perhaps half the surface. When potatoes were first given to them they impaled them upon skewers, after the manner of cooking eels, and sat watching till the oil should drop from them. Their canoes are ingeniously made of small sticks carefully tied together, as there is no wood on the island suitable for a solid canoe."

Considering how comparatively soon his visit followed upon the atrocities recorded by Mr. Shand, it is difficult to understand how the good Bishop could have been kept so much in the dark about the true history of the Maori usurpation as his remarks would lead one to suppose. It is not difficult to believe that whoever invented the title "Elder brother of the Bishop" for the unfortunate Moriori was gifted with a sense of humour, but the "amusing stories" of the first invasion must surely have been very

carefully selected before they were allowed to come to the ears of the distinguished visitor.

With the advent of European settlers the condition of the Morioris was doubtless greatly improved. As, however, the Maori occupation of the island took place prior to the treaty of Waitangi, their ownership of the land by right of conquest has been admitted, with the exception of 2,000 acres, which they were obliged to set apart as a reserve for their former slaves, of whom the remnant appear now to be very well treated, and to live on terms of equality with both Maoris and Europeans. The younger ones, at any rate, dress like Europeans and follow the same occupations; in fact, they have become so completely civilized as to be no longer of much scientific interest.

The extent of the Moriori population in former years is still attested by the immense quantity of human remains with which the shores of the island are littered, and by the abundant evidence of native handiwork. At intervals along the low sandhills which fringe the greater portion of the shore, old burying places and huge shell mounds or kitchen middens are still to be met with.

It was the custom of the race to bury some at any rate of their dead in the sand by the sea shore, in a sitting posture, facing the west, with the elbows down and the knees up. In many places the remains have been exposed by the wind, and the shore is strewn with skulls and bones as if it had been a battlefield. Owing doubtless to the ease with which graves are scooped out in the loose sand, the Maoris adopted a similar custom on the island, so that it is now by no means easy to say whether any particular skull picked up belonged to one of the conquered or one of the conquering race. The only safe plan for those who wish to obtain specimens for scientific purposes is to dig out the entire skeleton, when the sitting

posture may be regarded as sufficient proof of Moriori origin, for the Maoris appear to have buried in a horizontal position. At one locality close to the chief centre of population, when out riding on the shore, I came upon a place where the sand cliff was crumbling away and Maori coffins were tumbling out in fragments and discharging their contents in ghastly medley—in one the remains of a man, with an old tooth brush, numerous buttons and clay pipes close by; in another the remains of a child with the leg bones sticking out of the little boots, for they appeared to have been buried in their clothes and with their personal effects.

Although human remains are left to be kicked about on the beach by the hoofs of the horses in the most careless manner, yet the Maoris and half-castes have the strongest objection to anyone interfering with them. One of them tried to persuade me that any such interference was punishable, by fine, though I believe there is no power on the island authorised to inflict such a penalty. The Maoris, however, are very powerful; being the owners of much of the land they can make things uncomfortable in many ways if they choose to do so, so that it is necessary for the sake of peace and quiet to be careful, and observe their prejudices as much as possible—though it certainly seems a little strange that while but a short time ago their ancestors had no objection to eating the flesh, they should at the present day so strongly object to the removal of the bones. Possibly there is some superstitious feeling about it, or perhaps they fear that the remains of their own people might likewise be disturbed. I had the pleasure of being hospitably entertained by one half-caste who felt so strongly on the subject that he had fenced in an old Moriori burying place on his own property to keep the stock away from it, with the unexpected and

very pleasing result that the great forget-me-not or *Myosotidium*, elsewhere almost exterminated by the stock, has begun to spread again vigorously in this locality.

At Wharekauri, Mr. Chudleigh's estate in the northern part of the island, I saw many bones lying beneath the trees in a dense thicket near the shore, and was informed that the Morioris sometimes tied their dead to trees in erect postures, with a stick in hand pointing upwards to represent a pigeon spear—the bodies being tied with the stems of that curious climbing plant, the supple jack of the settlers (*Rhipogonum scandens*).

Mr. Gilbert Mair, in a paper read before the Wellington Philosophical Society in 1870,* also refers to this mode of burial. He says: "In some instances the corpses were placed upright between young trees, and then firmly bound round with vines, and in course of time they became embedded in the wood itself; sometimes they were placed in hollow trees. Several skeletons have lately been discovered by Europeans in trees which they were cutting up for firewood, &c. In other cases the corpses were placed on small rafts, constructed of the dry flower stems of the flax; water, food, fishing lines, &c., were then placed by them, and they were set adrift and carried out to sea by the land breeze. Not long ago an American whaler discovered one of these rafts, with a corpse seated in the stern, many miles from land. Not knowing that it had been set adrift purposely, the captain had a rope attached to it, and towed it into Whangaroa Harbour, much to the annoyance of the natives."

In considering the funeral customs of the Morioris, we must certainly take into account the extraordinary tree carvings so abundant in some parts of the island. A good painting of some of these, by Miss Stoddart, may be seen

* *Transactions of the New Zealand Institute*, Vol. III., 1870, p. 311.

in the Canterbury Museum,* which has also recently acquired some actual specimens. Mr. Travers likewise has to some extent dealt with and illustrated them in the *Transactions and Proceedings of the New Zealand Institute.* Whilst on the Island I myself made sketches of several of the carvings, which will be reproduced in the same publication.

The figures are commonly about three feet in height, and those which I saw evidently represented the human skeleton in a sitting posture, the elbows pointing down and the knees up, nearly or quite touching the elbows. Some of them have unmistakable ribs, while the head is commonly depicted with a curious deep notch on top. They appear always to have been carved in the bark of the Kopi or Karaka tree, whose large succulent fruits formed a staple article of food amongst the natives. It has been suggested that they might have been placed on the fruit trees as marks of ownership, or that they might have been intended to represent tutelary deities. The few remaining Morioris appear to know little or nothing about them, while the Maoris seem to have had a curious idea that the carvings were a sign that the Moriori race was doomed. For my own part I am inclined to believe, as already indicated, that they are connected with burial customs. It seems certain that one of the ancient methods of disposing of the dead amongst the Morioris was by so-called "tree-burial." This custom appears to have been abandoned in later times, probably under missionary influence. The custom of carving figures of skeletons upon the trees may then have been instituted with a view to averting the supposed evil consequences of abandoning an ancient rite, for the Morioris were extremely superstitious, and this may have been the origin

* At Christchurch, New Zealand.

of the Maori idea that they indicated the doom of the race.' Indeed, it is said that the Maoris attributed the extinction of the Morioris largely to the infringement of their own "tapu," an explanation which they may have found very convenient under the circumstances. The fact that the Kopi tree was always selected for the purpose of carving may be explained readily enough by the comparatively large size of the trunk and the peculiarly suitable character of the smooth bark.

There are also rude rock-carvings on the Island, but these are of quite a different type. At the entrance of a shallow cave or rock shelter at Maroroa, the soft rock is scored with bird-like figures in endless repetition, which are supposed possibly to represent shags.

The Moriori idea of carving, whatever they may have intended to represent, appears to have been extremely crude. Their figures were doubtless to a large extent conventionalized, but the inferiority to the Maori of New Zealand, both in conception and execution, is very remarkable, considering the undoubtedly close relationship of the two races. Easy conditions of life do not, in this case, appear to have conduced to the development of the artistic faculty. As manufacturers of useful implements of various kinds, they appear to have been much more successful. Stone clubs and chisels, bone fish-hooks and other manufactured articles have been found in abundance, while they seem to have been very fond of using shark's teeth for personal adornment.

The most interesting relic which I myself obtained on the island was a piece of curiously carved whalebone, picked up in an old Moriori burying place by one of the residents, Mr. Abner Clough. This I believe to be a fairly typical example of that remarkable and widely-spread instrument of primitive races known to ethno-

logists as the "bull-roarer." The specimen in question is probably of ancient date, the whalebone of which it is made being honeycombed with decay. It is broad and flat, and the edges are notched, while at one end there is a larger notch, presumably for fastening a string; the broad, flat surfaces are ornamented with grooves. Much has been written of late years about the "bull-roarer," which, as a toy, is familar to many an English schoolboy. It is essentially a noise-making instrument. The schoolboy takes a thin wooden lath, notches the edges, ties a string to one end, and whirls it round rapidly in the air, thereby producing a peculiar humming sound very suggestive of wind.

In different modifications the "bull-roarer" is distributed amongst primitive races over perhaps the greater part of the habitable world, and is used for an extraordinary variety of purposes, especially in connection with sacred rites or mysteries. For some reason or other it was commonly "tabooed" to women. Professor Haddon has written an extremely interesting chapter on the subject in his work on the "Study of Man," and has there tabulated the uses and distribution of this remarkable instrument. What the Morioris used it for will probably now for ever remain a mystery. Mr. Shand had never heard of such an instrument existing amongst them, but this might readily be accounted for if, as amongst the Australians, the "bull-roarer" was sacred. Probably, indeed, amongst the Morioris it was highly "tapu," for according to our authority these people "possessed the 'tapu' in all its forms and terrors." Whatever they may have used it for, however, the fact that they possessed such an instrument in such a remote corner of the earth's surface is in itself extremely interesting, and its somewhat peculiar form may, perhaps, eventually throw some light

upon the source from which the aboriginal population of Chatham Island was derived.

At the present day the population of the Chatham Islands numbers only some 300, of whom about half are Europeans, and the remainder mostly Maoris or half-castes. The only industry at present carried on in the Islands to any extent is sheep farming, the wool, and often the live sheep also, being exported to New Zealand. Owing to the infrequency of communication with the rest of the world, the population is still very much isolated, and in some respects remains in a more or less primitive condition. Thus there is hardly any formed road in the island, and as a consequence the horses never have to be shod. Everybody rides, but ordinary wheeled vehicles, except for carting wool, &c., are almost unknown. Instead of driving your carriage you drive your sledge, a truly primitive conveyance with runners in front and wheels behind, having the great advantage that it will go practically anywhere. The education of the islanders is well looked after by the New Zealand Government, and I believe at the time of my visit there were no less than six establishments on Chatham and Pitt Islands requiring to be visited by the school-inspector!

What the future of these remote islands may be it is extremely difficult to forecast. If the fishing industry, for which they seem especially well suited, is ever largely developed it may, together with the sheep farming industry, support a large population; as large, perhaps, as in the most flourishing days of the Moriori; but, in order that this may come about, the export trade will have to be developed and the means of communication with New Zealand greatly improved.

In conclusion, I would venture again to point out that much laborious research is still required to place our know-

ledge of the Biology of the Chatham Islands on a satisfactory footing. This research should be undertaken and, I am glad to say, to a large extent is being undertaken, before it is too late. The Morioris are already practically extinct, and the fauna and flora are following them under the baneful influence of civilisation. I must also apologise for the sketchy and imperfect character of this lecture, but I hope I have said enough to justify the belief that the study of even one small group of islands in the midst of the open ocean may greatly add to our biological knowledge, and bring into clear light many of the fundamental principles of life, such, for example, as the influence of isolation upon the evolution of plants and animals, and the disastrous results which, sooner or later, are sure to follow upon any evasion of the struggle for existence.

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XIII. Folk-lore of the North American Indians, from the 'Jesuit Relations' (1611-1637).

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The 'Jesuit Relations and Allied Documents'* fill 73 volumes in the Cleveland (The Burrows Brothers Co.) edition of 1896, of which there is a copy in the Rylands Library. The French settlements in Canada began in 1501, and in 1610 there was a permanent post established at Quebec. The first Jesuit mission arrived in 1611, other missions being sent in 1625 and 1632, and at the beginning of the 18th century there were 30 mission stations.

The different missionaries sent in their journals and made out reports to their Superior at Quebec or Montreal. The Superior made up a Relation based upon such reports, which was annually sent to the Provincial of the Order in France. There it was re-edited and published from 1632 to 1673. The Jesuit did not, as has been said, "lead the way." He came in the track of the fur traders—the *coureurs de bois*—partly to look after his own people, and also to convert the Indians. The Jesuits had their difficulties. The civilian officials were, to begin with, often Huguenots and did not want the Jesuits. There were descents made by the English, which sent the missionaries back to Europe. There was the drink traffic, about which their complaints have quite a modern sound. The impres-

* The References to the volumes of the 'Relations' are given in the text of the paper.

sion left by the 'Relations' is one of great ability, absolute devotion, and indomitable perseverance, seasoned with a Gallic gaiety, which carried the good fathers through all their troubles and privations.

My object is to consider these Relations, not as a record of missionary enterprise, but as a record of savage customs, usages and beliefs, given at first hand by skilled witnesses. The object of the Jesuits was not that of, for instance, Messrs. Spencer and Gillen in Central Australia, *i.e.*, to give simply an accurate and scientific account of savage custom and belief. Their object was to study the savages with a view to finding out the weak points in their armour for purposes of conversion. They are not the less skilled or accurate in their accounts for that reason. Their first view of the natives was not favourable; they found them savage, full of bad habits, wanderers without possessions or love of country, lazy, gluttonous, profane, treacherous, cruel, lewd, and vain-glorious. The language was difficult to learn, and the savages made bad teachers. It was deficient in words suitable for the expression of even the most common ideas—though with great wealth of words applicable to common objects. Further, their religion is said to consist of incantations, dances, sorcery; they sought baptism almost entirely as an aid to health, and came to the missionaries for what they could get.*

The savages believe in two main sources of disease—desires in the mind of the patient and evil practices by an enemy. Desires vex the body till they are gratified. Soothsayers can look into the mind and ascertain such

* Four groups of tribes may be distinguished—

1. Algonkin group (Montagnais, &c.).
2. Iroquois group (the "five nations" and Hurons).
3. Southern group (Chickasaws, &c.).
4. Dacota or Sioux group.

desires. Whatever first occurs to the soothsayer is the desire. The relatives must gratify it and the patient gives the soothsayer a share. (i., 259.)

One way of finding out the cause of illness is by dreams. Dreams are of very great importance, as is shown by the following passage :—

They have a faith in dreams which surpasses all belief; and if Christians were to put into execution all their divine inspirations with as much care as our Savages carry out their dreams, no doubt they would very soon become great Saints. They look upon their dreams as ordinances and irrevocable decrees, the execution of which it is not permitted without crime to delay. A Savage of our Village dreamed this winter, in his first sleep, that he ought straightway to make a feast ; and immediately, night as it was, he arose, and came and awakened us to borrow one of our kettles.

The dream is the oracle that all these poor Peoples consult and listen to, the Prophet which predicts to them future events, the Cassandra which warns them of misfortunes that threaten them, the usual Physician in their sicknesses, the Esculapius and Galen of the whole Country,—the most absolute master they have. If a Captain speaks one way and a dream another, the Captain might shout his head off in vain,—the dream is first obeyed. It is their Mercury in their journeys, their domestic Economy in their families. The dream often presides in their councils ; traffic, fishing, and hunting are undertaken usually under its sanction, and almost as if only to satisfy it. They hold nothing so precious that they would not readily deprive themselves of it for the sake of a dream. If they have been successful in hunting, if they bring back their Canoes laden with fish, all this is at the discretion of a dream. A dream will take away from them sometimes their whole year's provisions. It prescribes their feasts, their dances, their songs, their games,—in a word, the dream does everything, and is in truth the principal God of the Hurons. (x., 167.)

Further illustration of the importance attached to dreams in relation to healing is given in the following :—

His brother-in-law came to tell him that he had dreamed his niece would recover, if they had her lie upon a sheepskin painted with various figures ; a search was made for one immediately ; one was found, and they painted thereon a thousand grotesque figures, canoes, paddles, animals, and such things. The Fathers, who had not yet instructed this girl, urged earnestly that this remedy was useless ; but they must try it. The patient rested upon these paintings, but received no real benefit. Another Charlatan was of the opinion that, if they gave the sick girl a white sheet as pillow, upon which had been drawn pictures of men singing and dancing, the sickness would disappear. They began immediately to paint men upon a sheet, but they

made nothing but monkeys, such good painters are they; this remedy succeeded no better than the first. The poor girl lay down upon this sheet without resting, and without recovering. What cannot the natural affection of fathers and mothers do for their children? These good people sought everywhere the health of their daughter, except in Him who could have granted it. They consulted a famous Sorceress, that is, a famous jester. This woman said she had learned,—whether from Manitou or some one else, I cannot say,—that they would have to kill a dog and that the men should make a feast of it. Futhermore, that they would have to make a beautiful robe of Deer skin, trim it with their red matachias made of Porcupine quills, and give it to the patient; and that she would thus recover.

While they were preparing this feast, a Savage dreamed that for the recovery of this girl, they would have to prepare a banquet of twenty head of Elk. Now the girl's parents were placed in great anxiety, for, as there was but little snow, they could not pursue and much less capture the Elk. In this great difficulty, they consulted the Interpreters of dreams; it was decided that they must change the twenty head of Moose to twenty big loaves of bread, such as they buy from our French, and that this would have the same effect. They were not mistaken, inasmuch as this bread and this dog feast did nothing but fill the stomachs of the Savages; and this is all the twenty Moose heads could have done, for to cure the sick, neither banquets nor beautiful robes avail. (viii., 261.)

As an illustration of this principle of make believe we may instance the Roman *cervaria ovis* when a sheep took the place of a deer which was not forthcoming.

It is the duty of the Sorcerers (also called Autmoins, Pilotoys, Soothsayers, and other names) to interpret dreams (xii., 9). It is recognised that all dreams are not true, but it is not easy to say how a distinction between true and false is made. A person of no importance, at any rate, is not likely to have a dream of any consequence. (x., 171).

Miss Kingsley (*Travels in West Africa*) says that in West Africa dreams are not of so much importance. In Melanesia however they are of importance. A man is ill: he calls in a professional dreamer, who takes his tobacco and goes to sleep. In sleep his soul goes off to the place where the sick man has been working, meets a ghost there and learns its name. The ghost tells him that the

sick man has been trespassing, therefore his soul has been taken away and put in a magic fence and now the man is ill. The dreamer asks pardon for the man and begs back his soul, which in the end is released.*

In sleep or fainting the soul has gone out of a man. In Grimm's *Teutonic Mythology* (iii., 1082, Stallybrass' edition) there is a story of King Gunthrum. He once went to sleep, and the follower who was with him said a little beast like a snake ran out of his master's mouth and made its way to a stream which it could not get over. He lays his sword across the water and the creature runs over and goes into a hill. After some time it returns the same way into the sleeper, who presently wakes up and tells how in a dream he had crossed over an iron bridge and gone into a mountain filled with gold.†

The treatment of illness by a sorcerer is described in the following passage :—

Now if the sick man eats what is given him, it is a good sign ; otherwise, they say that he is very sick, and after some days (if they can) they will send for the *Autmoin*, whom the Basques call *Pilotoys* ; *i.e.*, sorcerer. Now this *Pilotoys*, having studied his patient, breathes and blows upon him some unknown enchantments ; you would say that these chest winds ought to dispel the vitiated humors of the patient.

If he sees after some days, that notwithstanding all his blowing the evil does not disappear, he finds the reason for it according to his own ideas, and says it is because the devil is there inside of the sick man, tormenting and preventing him from getting well ; but that he must have the evil thing, get it out by force and kill it. Then all prepare for that heroic action, the killing of Beelzebub. And the *Autmoin* advises them to be on their guard, for it can easily happen that this insolent fellow, seeing himself badly treated by him, may hurl himself upon some one of the crowd, and strangle him upon the spot. For this reason he allots to each one his part of the farce ; but it would be tedious to describe, for it lasts fully three hours.

The sum and substance of it is that the juggler hides a stick in a deep hole in the ground, to which is attached a cord. Then after various chants, dances, and howls over the hole, and over the sick man, who is not far away, of such kind that a well man would have enough of it to deafen him, he takes a

* Codrington, *The Melanesians, their Anthropology and Folk-Lore*, p. 208.

† Cf. Frazer, *Golden Bough*, i., 247 ff.

naked sword and slashes it about so furiously that the sweat comes out in great drops all over his body and he froths like a horse. Thereupon the spectators, being already intimidated, he, with a frightful and truly demoniac voice, redoubles his roars and threats that they must take care, that Satan is furious and that there is great peril. At this cry the poor dupes turn pale as death, and tremble like the leaf upon the tree. At last this imposter cries out in another and more joyous tone : "*There is the accursed one with the horn: I see him extended there at bay and panting within the ditch.* But courage, we must have him all and exterminate him entirely." Now the audience being relieved, all the strongest with great joy rush for the cord to raise Satan, and pull and pull. But they are far from getting him, as the *Autmoin* has fastened the stick too well. They pull again as hard as they can, but without success, while the *Pilotoys* goes, from time to time, to utter his blasphemies over the hole ; and, making as if to give great thrusts to the diabolical enemy, little by little uncovers the stick which, at last, by hard pulling, is torn out, bringing with it some rubbish, which the charlatan had fastened to the end, such as decayed and mouldy bones, pieces of skin covered with dung, etc. Then they are all overjoyed : wicked Lucifer has been killed. *Nepq. Nepq.* Stop, do you see his tracks? Oh victory! You will get well, sick man ; be of good cheer, if the evil is not stronger than you, I mean if the Devil has not already given you your deathblow.

For this is the last Scene of the farce. The *Autmoin* says, that the Devil being already killed, or seriously hurt, or at least gone away, whether very far or not, I do not know, it remains to be seen if he has given a death wound to the patient. To guess this he will have to dream ; indeed he is in great need of sleep, for he has worked hard. Meanwhile he gains time to observe the crisis of the disease. Having slept well and dreamed, he looks again at the patient and, according to the symptoms which he observes, he declares that he is either to live or to die. He is not so foolish as to say that he will live, if the symptoms are not encouraging. He will then say, for instance, that he will die in three days. Hear now in what a fine fashion he verifies his prophecies. In the first place the sick man, since he has been thus appointed to die, does not eat, and they no longer offer him anything. But if he does not die by the third day, they say that he has something of the Devil in him, I know not what, which does not permit him to die easily, so they rush to his aid. Where? To the water. What to do? To bring kettles full of it. Why? To pour the cold water over his navel, and thus extinguish all vital heat, if any remain to him. He is indeed obliged to die the third day, since if he is not going to do it of himself, they kill him. (iii., 119 ff.)

The object of the dancing, singing, and the like, is to work the soothsayer up to a state of possession in which he can employ his skill.* Father Pijart (xii., 26) reports

* Tylor, *Prim. Culture*, ii., 130.

that a soothsayer in a frenzy took a red hot stone from the fire and put it between his teeth, after which the lips and tongue were not burned. To fast (vi., 209) for as many as 8 or 10 days, with intervals of howling, was also a practice of Canadian sorcerers to make their "bodies and minds free and light, and so prepared for dreaming."* The pouring of cold water was, according to the Jesuit fathers, intended to justify the diagnosis of the sorcerer. Sometimes such a practice has a different object. Just as when a person is dead it is important to drive away the ghost, so before they are dead the aim is to prevent the soul from leaving the body. This can be done by making a noise, so as to frighten the soul back and prevent the patient from sleeping, when a soul so easily slips out of the body. The dashing of cold water over a patient has the same effect, and instances are given from China and Siam.† In the Niger Delta, if the patient is insensible, pepper is put into the nostrils and eyes, and the mouth propped open with a stick. The whole crowd of relations and friends yell out the patient's name, crying, "Hi! don't you hear? Come back!"

Another instance of the treatment of sickness in the case of a child is the following:—

> The greatest sorcerer they have among them, according to the Interpreter, who arrived shortly afterward, sang and blew upon the child to cure him. They had made a little retreat where the child was. Two or three times I tried to get near it, but was not permitted. The savages stopped me every time. I waited until this fine doctor had treated his patient; the child, naked as one's hand, lay in a cradle of bark, upon pulverised rotten wood. He was burning with a high fever; and this charlatan to cure him, was beating upon and whirling around an instrument full of little stones, made exactly like a tambourine. With all this he howled immoderately. In a word, he and his companion, in order to cure this little boy of a fever, made enough noise to give one to a healthy man. The sorcerer approached the patient, and blew all over the body, as I conjectured, for I could not see

* Tylor, *Prim. Culture.*, xi., 413.

† Frazer, *Journ. Anthrop. Inst.*, xv., 64.

what he was doing, but I heard his breath drawn from the depths of his stomach. He beat the tambourine in the child's ears, during which there was great silence among the other savages who were in the same cabin. His medicine having been given, he called me and told me I might then see the child, and that I should give him my opinion ; as to him, he believed that the child had something or other black in his body, and it was that which made him sick. Behold the result of this great noise. I approach, I feel the pulse of the child, I discover a raging fever, and I tell him that he has a sickness which we call fever, that he must be left to rest, and not be killed by this great noise which makes him worse ; that recently I had an attack of fever, and that rest had cured me. The sorcerer replied, "That is very good for you people ; but, for us, it is thus we cure our sick." (v., 235 ff.)

The blowing over the body spoken of in this extract is often referred to in the 'Relations,' and is possibly identical with the spraying still practised by the North American Indians as a precaution against disease. Water, sweetened with sugar and the juice of berries, is taken into the mouth of the operator and ejected as spray over the bowed head of the patient.*

The following passage is a further illustration of the use of the drum and other methods of making noise.

As to this drum, it is the size of a tambourine, and is composed of a circle three or four finger-lengths in diameter and of two skins stretched tightly over it on both sides ; they put inside some little pebbles or stones, in order to make more noise ; the diameter of the largest drums is of the size of two palms or thereabout ; they call it *chichigouan*, and the verb *nipagahiman* means, "I make this drum sound." They do not strike it, as do our Europeans ; but they turn and shake it, to make the stones rattle inside ; they strike it upon the ground, sometimes its edge and sometimes its face, while the sorcerer plays a thousand apish tricks with this instrument. Often the spectators have sticks in their hands and all strike at once upon pieces of wood, or upon hatchet handles which they have before them, or upon their *ouragans ;* that is to say, upon their bark plates turned upside down. To this din they add their songs and their cries, I might indeed say their howls, so much do they exert themselves at times ; I leave you to imagine this beautiful music. This miserable sorcerer with whom my host and the renegade made me pass the winter, contrary to their promise, almost made me lose my head with his uproar ; for every day—toward nightfall, and very often toward midnight, at other times during the day—he acted like a madman. For quite a long time I was sick among them, and although I begged him to moderate a little and to give me some rest, he acted still

* *Archæological Report of Ontario for 1898.*

worse, hoping to find his cure in these noises which only made me worse. (vi., 187.)

The power of the sorcerers is great.

They say that the Sorcerers ruin them ; for if any one has succeeded in an enterprise, if his trading or hunting is successful, immediately these wicked men bewitch him, or some member of his family, so that they have to spend it all in Doctors and Medicines. Hence, to cure these and other diseases, there are a large number of Doctors whom they call *Arendiouane*. These persons, in my opinion, are true Sorcerers, who have access to the Devil. Some only judge of the evil, and that in divers ways, namely, by Pyromancy, by Hydromancy, Necromancy, by feasts, dances, and songs ; the others endeavour to cure the disease by blowing, by potions, and by other ridiculous tricks, which have neither any virtue nor natural efficacy. But neither class do anything without generous presents and good pay. (viii., 123.)

A fuller account of the method pursued by sorcerers wishing to injure their enemies is given in the following passage :—

Here is one of the methods employed by the wicked ones to kill their countrymen. Some one has told me that they had formerly tried to use these deviltries against the French, but that they could not make them sick. If the Christian realized his own dignity he would hold it in high esteem. A Sorcerer wishing to kill some one, enters his Tent and summons the Genii of the light, or those who make the light ; they call them thus, and we call them Devils. When they arrive, he sends them after the soul of him, or of those, whom they wish to kill. If these persons belong to another Nation, they change their name, lest their relatives, getting wind of the affair, take vengeance on the sorcerer. The Genii bring these poor souls in the form of stones, or in some other shape. Then the sorcerer strikes them with blows of javelins or hatchets, so hard that the blood runs down from them, so copiously that the javelin or the hatchet remains all stained and red with it. When this is done, the one whose soul had been struck falls sick, and languishes unto death. See how these poor people are deluded by the Demons. When one Savage hates another, he employs a sorcerer to kill him in this way ; but they say that if the sick man happens to dream who it is that has bewitched him, he will get well and the sorcerer will die. These Genii, or makers of Light, induce them to believe that they greatly love their Nation, but that the wicked Manitou prevents them from procuring for it the blessings they would desire.

They imagine that he who longs for, or desires the death of another, especially if he be a sorcerer, will often have his wish gratified ; but also the sorcerer who has had this wish dies after the others. It is strange to see how these people agree so well outwardly, and how they hate each other within. They do not often get angry and fight with one another, but in the depths of

their hearts they intend a great deal of harm. I do not understand how this can be consistent with the kindness and assistance that they offer one another. (xii., 9 ff.)

Death is nearly always ascribed to witchcraft operating by wishes or imprecations or charms.

It is a question of killing one another here, they say, by charms which they throw at each other, and which are composed of Bears' claws, Wolves' teeth, Eagles' talons, certain stones, and Dogs' sinews. Having fallen under the charm and been wounded, blood pours from the mouth and nostrils, or it is simulated by a red powder they take by stealth; and there are ten thousand other absurdities, that I willingly pass over. The greatest evil is, that these wretches, under pretext of charity, often avenge their injuries, and purposely give poison to their patients, instead of medicine. What is very remarkable is their experience in healing ruptures, wherein many others in these regions are also skillful. The most extraordinary superstition is that their drugs and ointments take pleasure, so to speak, in silence and darkness. If they are recognised, or if their secret is discovered, success is not to be expected. (x., 209.)

Some deaths, such as death by drowning or by lightning, are not attributed to witchcraft, but to the action of higher powers. Such dead bodies, as we shall see later on, are treated in a different way from other dead bodies. The Montagnais savages, we are told (xii, 7), give the name "Manitou" to all nature superior to man, good or bad.

As to the method of procuring charms, the following passage will serve as an illustration:—

One of these Sorcerers or Jugglers told me that occasionally the devil speaks to some Savage, who hears only his voice, without seeing anyone. He will say to him, for example, "Thou wilt find a stone upon the snow, or in such a place, or in the heart, or the shoulder, or some other part of an Elk, or of another animal; take this stone, and thou wilt be lucky in the chase." He assured me that he had found one of these stones in the heart of an Elk, and that he had given it to a Frenchman. "Hence I shall kill nothing more," said he.

He also said that the Devil made himself known through dreams. A Moose will present itself to a man in his sleep, and will say to him, "Come to me." The Savage, upon awaking, goes in search of the Moose he has seen. Having found it, if he hurls or launches his javelin upon it, the beast falls stone-dead. Opening it, he occasionally finds some hair or a stone in its body, which he takes and keeps with great care, that he may be fortunate in finding and killing many animals.

Moreover, he added that the Demons taught them to make ointments from toads and snakes, to cause the death of those whom they hate. If he tells the truth, there is no doubt they have communications with the Devil. I believe that from this superstition or notion has sprung a custom the Savages observe, of having a little bag so especially for their own use, that no one else would dare look inside of it; they would be greatly offended thereat, perhaps even so much as to kill the other. They are unwilling that any one should see this stone, or similar object, if they have one; and one of them said to me one day, "In this way thou wilt know whether a Savage really desires to believe in God, if, having one of these stones, he gives it to thee." (xii., 9 ff.)

This passage serves as an illustration of Fetishism, the "doctrine of spirits embodied in or attached to or conveying influence through certain material objects."

Similar practices to those described in the passages quoted are to be found amongst savages in different parts of the earth. Very often the wizard or sorcerer works by getting hold of something belonging to the person to be injured—his nail clippings, hair, blood, &c., upon which the spirits can be set to work. There are different sorts of spirits. There are the ghosts or souls of the dead—mostly insignificant, as in life, but some of them powerful. Then there are spirits of a higher order, not ghosts of dead men. Such with the Indians are the Genii of the Light, the Manitous and Okis, beneficent if you know the way to get them on your side.

It is a common belief that the soul or spirit is in the blood. The blood is sacred and dangerous. Many savages abstain from blood. In other cases sacred persons such as the Flamen Dialis at Rome, have to abstain from blood. Conversely, blood is sometimes drunk for purposes of inspiration—to get the spirit into a man—or, as with the Indians, the blood of a brave enemy is drunk to get his courage. In the Odyssey* of Homer, Odysseus revives the feeble ghosts of the dead by giving them blood to drink, because the blood is the life.

* *Od.*, xi., 35.

Names, again, are things not to be trifled with (i., 207). The Jesuits found that the Indians did not like to tell their names. Similarly, Australian savages have each a secret name which is never to be uttered except upon the most solemn occasions, for fear it should be exposed to magical influence.*

Savages live in a world of mysterious dangers, which are ascribed to living agencies who can be controlled and directed by those who know the proper way.

Some natural cures for sickness the Indians had, such as sweating (vi., 191). A low tent of bark was put up in the cabin, covered with fur robes; five or six heated stones were put in, and the patient entered. Such a remedy is found amongst other savages, as, for instance, on the West Coast of Africa, where the Bantus dig a hole in the earth and put in herbs and boiling water.† The patient enters, and a coating of clay is put over him, leaving the head free. This sweating was used by the Indians as a means of magic, to secure good hunting, for instance, and as such was forbidden to the Jesuit converts.

They sing and make these noises also in their sweating operations. They believe that this medicine, which is the best of all they have, would be of no use whatever to them if they did not sing during the sweat. They plant some sticks in the ground, making a sort of low tent, for, if a tall man were seated therein, his head would touch the top of this hut, which they enclose and cover with skins, robes and blankets. They put in this dark room a number of heavy stones which they have had heated and made red-hot in a good fire, then they slip entirely naked into these sweat boxes. The women occasionally sweat as well as the men. Sometimes they sweat all together, men and women, pell mell. They sing, cry and groan in this oven, and make speeches; occasionally the sorcerer beats his drum there. I heard him once acting the prophet therein, crying out that he saw Moose; that my host, his brother, would kill some. I could not refrain from telling him, or rather those who were present and listened to him as if to an oracle, that it was

* Spencer and Gillen, *Native Tribes of Central Australia*, p. 139.

† Miss Kingsley, *Travels in West Africa*, p. 431.

indeed quite probable that they would find a male, since they had already found and killed two females. When he understood what I was driving at, he said to me sharply, "Believe me, this black robe has no sense." They are so superstitious in these uproars and in their other nonsense, that if they have sweats in order to cure themselves, or to have a good hunt, or to have fine weather, [they think] nothing would be accomplished if they did not sing, and if they did not observe these superstitions. I have noticed that, when the men sweat, they do not like to use women's robes with which to enclose their sweat boxes, if they can have any others. In short, when they have shouted for three hours or thereabouts in these stoves, they emerge completely wet and covered with their sweat. (vi. 189 ff.)

In the different villages there were endless feasts feasts of farewell to the dead, of thanksgiving, for display, before going to war. Feasting took rank with other practices which we have already described.

This is a sorcerer's account of himself.

"I give feasts at which all must be eaten. I sing loudly during these feasts. I believe in my dreams. I interpret them and the dreams of others. I sing and beat my drum in order to be lucky in the chase and cure sickness. I consult those who have made the light (Genii). I kill men by my sorceries and with my contrivances. I take robes and other gifts for curing the sick. I order that these should also be given to the sick themselves. What dost thou find bad in all that?" (xi., 263.)

The Jesuits however forbade their converts the eat-all feasts, the belief in dreams, and the sweating to secure good hunting.

The different kinds of feasts are described in the following passage:—

They have two kinds of feasts—one at which everything is eaten; the other at which the guests eat what they please, carrying away the rest to divide with their families. This last feast seems to me praiseworthy, for there is no excess, each one taking as much as he likes of the portion given to him; indeed, I would venture to say that it is a happy invention to preserve friendship among them, and for each to help feed the others. For usually the heads of families only eat a part of their share, carrying the rest to their wives and children. The trouble is that their feasts come too often. In the famine through which we passed, if my host took two, three, or four beavers, immediately, whether it was day or night, they had a feast for all the neighbouring savages. And if those people had captured something, they had one also at the same time; so that, on emerging from one feast, you went to another, and sometimes even to a third and a fourth. I told them

that they did not manage well, and that it would be better to reserve these feasts for future days, and in doing this they would not be so pressed with hunger. They laughed at me. "To-morrow" (they said) "we shall make another feast with what we shall capture." Yes, but more often they captured only cold and wind.

As to their "leave-nothing" feasts, they are very blamable; and yet this is one of their great devotions, because they make these feasts in order to have a successful chase. They must be very careful that the dogs taste nothing of this or all will be lost, and their hunting will be worthless. And notice that, the more they eat, the more efficacious is this feast. Hence it happens that they will give, to one man, what I would not undertake to eat with three good dinners. They would rather burst, so to speak, than to leave anything. True, they can help each other; when one can eat no more, he begs his companions to assist him; or else he may pass the remains of his part along to the others, who each one take some of it, and after all this, if anything remain, it is thrown into the fire. The one who eats the most is the most admired. (vi., 281 ff.)

Certain practices were observed with reference to the bones of the animals devoured at the feasts.

The Savages do not throw to the dogs the bones of female Beavers and Porcupines,—at least, certain specified bones; in short, they are very careful that the dogs do not eat any bones of birds and of other animals which are taken in the net, otherwise they will take no more except with incomparable difficulties. Yet they make a thousand exceptions to this rule, for it does not matter if the vertebræ or rump of these animals be given to the dogs, but the rest must be thrown into the fire. Yet, as to the Beaver, which has been taken in a trap, it is best to throw its bones into a river. It is remarkable how they gather and collect these bones, and preserve them with so much care, that you would say their game would be lost if they violated their superstitions. As I was laughing at them, and telling them that Beavers do not know what is done with their bones, they answered me, "Thou dost not know how to take Beavers, and thou wishest to talk about it." Before the Beaver was entirely dead, they told me, its soul comes to make the round of the Cabin of him who has killed it, and looks very carefully to see what is done with its bones; if they are given to the dogs, the other Beavers would be apprised of it, and, therefore, they would make themselves hard to capture. But they are very glad to have their bones thrown into the fire, or into a river; especially the trap which has caught them is very glad of this. (vi., 211.)

The life of the animal was especially connected with the bones. The bones (it may be) would be broken by the dogs, and the existence of the animal after death impaired.*

Cf. Frazer, *Golden Bough*, ii., 416.

Another practice observed in connection with feasting is given in the following passage :—

They hold that fish are possessed of reason, as also the Deer and Moose ; and that is why they do not throw to the Dogs either the bones of the latter when they are hunting, or the refuse of the former when fishing ; if they did, and the others should get wind of it, they would hide themselves, and not let themselves be taken. Every year they marry their nets or Seines to two little girls, who must be only from six to seven years of age, for fear they may have lost their virginity, which is a very rare quality among them. The ceremony of these espousals takes place at a fine feast, where the Seine is placed between the two virgins; this is to render them fortunate in catching fish. Fish, they say, do not like the dead ; and hence they abstain from going fishing when one of their friends is dead. But lately, when they took up from the cemetery the bodies of their relatives and carried them into their Cabins, on the occasion of the feast of the dead, some brought into our Cabin their nets, alleging as a pretext the fear they had of fire,—for it is usually in this season that fire often ruins entire Villages ; that in our Cabin we were almost always moving about, and slept very little ; that we were at some distance from the Village, and consequently were in less danger in that respect. But all this was talk ; the true reason was, as we learned afterwards, that they were afraid their nets would be profaned by the proximity of these dead bodies. (x., 167.)

All things—men, animals, nets, traps, everything—have souls, something in them that works them, which is a shadow of the animate or inanimate object. Hail has intelligence (vi., 213), and hates a light, *e.g.*, a torch, because it mostly comes at night. The Thunder, again, is a bird (vi., 225) and eats snakes and trees. The Hurons objected to the Red Cross in front of the Mission hut, because it frightened the Thunder and so caused a drought.

Earth, sky, rivers, lake, dangerous rocks, &c., were all regarded by the Indians as animate. (x., 159.) This is rather the second stage recognised by Dr. Tylor in his account of animism. The rock is not regarded so much as being the body and as having a soul of its own, but as being the abode of a separate spirit or demon. Tobacco was offered to a dangerous rock in the river or rapids—put into a cleft. " Here is some Tobacco

which I offer thee, guard us, defend us, give us good trade." Similarly, according to Miss Kingsley, the Bantus pile up stones in homage at the foot of some big rock or tree, or cast a leaf from the canoe in passing some promontory.

Let us return to the human soul. Father Le Jeune was told that after death souls eat and drink. (vi., 177.) Hence when anyone dies the souls are given food. The souls go to a large village towards the setting sun. On the way they eat bark and old wood. The Milky Way is the path of the souls. When the souls get to their destination, they sit all day, elbows on knees—head between hands—in the position in which they are buried. At night they can see—they go and come, work and hunt. They hunt the souls of the dead beaver, porcupine, moose, &c., and walk about on the ghosts of snow shoes. What happens, asked the Jesuit, if the soul of a dead Indian kills the soul of a dead beaver with the ghost of a spear? Have I been there, and do I know, was the answer.

This is the general picture of existence after death. It is a shadow of life before death. The shadow world is like the present in all ways, but dimmer. One day in this world is worth a year in the under world, or, to quote Achilles from Homer, "I had rather be a serf on the land of a poor man than reign among the dead."* The blood which was the life has gone.

The corpse of the dead was borne out of the cabin through that part of it towards which the sick person was turned when he expired. (i., 261, &c.) The bark of the hut is raised for the purpose. "The common door is the door of the living not of the dead." The ghost of the dead was to have no right of way. The old Norsemen took the body of the dead through the wall of the house

* *Od.*, xi., 490.

in the same way as the Indians. In Siam the bearers give the coffin a run three times round the house to make the ghost giddy, so that it shall not know the way back.

The soul passes out through the chimney or opening at the top of the hut. To ensure that it does so, those present in the hut raise cries and beat the walls of the wigwam with sticks.

With some savages the corpse remains in the hut for a time till burial. During that time no fire must be lighted, no sharp iron tool left about for fear the ghost should hurt itself. Inmates must not eat for fear of swallowing the ghost. On the way to the grave the ghost of the dead is exposed to danger from evil spirits. The Chinese scatter bank notes (bad ones) on the road to occupy the demons, and ring bells to keep them off.*

What if a man supposed to have died turns up again? This is one of Plutarch's Roman Questions. "Why are they who have been falsely reported dead in a strange country, although they return home alive, not received nor suffered to enter directly at the door, but forced to climb up to the tiles of the house, and so to get down from the roufe into the house?" The reason is that the friends are doubtful whether the returned wanderer is really alive or not. He may be the ghost trying to get back into his old home—a dangerous visitor. It will, therefore, be best to treat him as a ghost, and not let him in at the regular entrance.

Amongst many nations there are legends of an attempted return of the dead to life in their proper bodily form. In Greece there is the story of Orpheus and Eurydice. With the Indians there is the story of a man who went to the village of the dead and brought back his sister's soul in one pumpkin and her brains in another.

* Cf. Frazer, *Journ. Anthrop. Inst.*, xv., 64.

Her body was then dug up and carried round a cabin with the pumpkin. No one was to look. Someone did look and the soul escaped.

The name of the dead was not to be mentioned, for fear apparently that the dead should hear and be displeased. With the Aruntas of Central Australia it is the near relations who must not mention his name. With them, indeed, widows must not speak at all for twelve months, except on their fingers. In the case of one tribe in Paraguay all have to change their names on the death of a chief. With an Australian tribe, on the lower Murray, if the name of the dead was also the name of a bird or beast the name of that bird or beast must be changed. With the Indians there was a custom of passing on the name of the famous dead. When the dead man's name had been given to another and presents offered to his relatives, then the body was said to have been "cached," or rather the dead resuscitated. Presents were made to the man who thus took the name of a dead chief and resuscitated him. The man who thus took the name of the dead would give a magnificent feast and then make a levy of the young men and go on a warlike expedition to perform some exploit. (x., 277.) As we shall see later on, this is a case of metempsychosis. The soul of the dead chief passes on to the successor, who takes his name, and in this way the famous captains never die. This belief in the resuscitation of the dead man's soul in his successor exists along with the belief in the continued existence of the souls of the dead in the Village of the Dead in the West.

The funeral rites next demand our attention. Amongst the Hurons the bodies are first put in tombs of bark raised upon four stakes 8 or 10 feet high in the village cemetery. The great mourning lasts for ten days; the lesser mourning for a year. Speeches are made in honour of the dead.

Mourning cries are raised, and amongst the Montagnais the faces of the mourners are daubed with black. In the case of profound grief it is the Huron practice to cut off a handful of hair from the back of the head.* In addition to this, other North American Indians (*e.g.*, Comanches, Sioux) scarify themselves, both men and women, especially the latter. These customs can, of course, be widely illustrated. In ancient Greece the mourning women tore their hair and cheeks and beat their breasts, and the men cut off locks of hair to give to the dead. It has been suggested† that the bulk of mourning customs, such as smearing the body with ashes, mud, paint, &c., mutilation and gashes, cutting off hair, wearing unusual clothes, are all means adopted for purposes of disguise, so that the ghost of the dead shall not recognise the living. But we have to remember that, besides the fear of ghosts of the dead, there is also a desire for continued fellowship with the kindred dead, under conditions, however, which will make such fellowship free from danger.‡ In the case of the Arunta tribe of Central Australia, it has recently been pointed out that there is no idea in smearing the bodies of the mourners with pipeclay, &c., of concealing their identity from the dead. The idea is rather to render the mourners more conspicuous, and prove to the dead that proper sorrow is being shown by the proper persons.§ The shedding of blood and the cutting off of hair are symbolical acts, the object of which is to maintain the bond of union with the dead. The Australians gash their bodies upon the graves. In the same way the priests of Baal‖ gashed themselves upon the altar, so that their blood

*The Montagnais "cut a tuft of hair from the dead man to present to his nearest relative." (vi., 211.)

† J. G. Frazer, *Journ. Anthrop. Inst.*, xv., 64.

‡ Robertson Smith, *Religion of Semites*, p. 370.

§ Spencer and Gillen, *Native Tribes of Central Australia*, p. 511.

‖ I. Kings, xviii., 28.

might renew the bond with their god and serve as a recommendation in his eyes. Not only do the living mourners gash their bodies, but in some cases they cut off and eat a bit of the dead body, or the corpse is raised up, a fire lighted underneath, and the mourners sit till the grease from the corpse drops upon them. Similarly with the hair. The hair of the living mourners is cut off and offered to the dead, and the hair of the dead is plucked and worn as a relic by the living. The action is reciprocal between the dead and the living.

With the dead the Hurons buried all that belonged to them—skins, bows, utensils, wigwams, &c., as well as provisions for the benefit of the soul. Presents are added by the survivors as tokens of regard. "The Hurons," says Father Breboeuf, "will strip themselves to give presents to their dead," or again, "if there be anything sacred to the Hurons, it is their law of burial." The practice of giving gifts to the dead, of burying or burning with them all that they are likely to need, is so general that I need scarcely illustrate it.* Father Le Jeune relates, to take a single instance, that a mother at the burial of her infant drew milk from her breast and burnt it in the fire for the benefit of the dead child.

The bodies of the dead Hurons remain in the local village cemeteries for a period variously given as 8, 10, or 12 years, until the time of the great Feast of the Dead, with which we may compare the Greek *νεκύσια*, or the mediæval All Souls' Day. At the Feast of the Dead the bodies were taken from the bark coffins and brought to the cabins, the bones were cleaned (except in the case of the most recently dead) and taken off to a common burial pit for eight or nine villages, where all met at a fixed time.

* Cf. Tylor, *Prim. Culture*, i., 458.

The reasons given by the Hurons for this Feast of the Dead were :—

1. That it helped to assuage the general grief.
2. That it entertained friends from a distance.
3. That the ghosts of the dead were pleased by the liberality shown and also by the food, in which they had their share.

For further illustration of these feasts of the dead I may refer to Dr. Tylor's *Primitive Culture.* The practice of re-burial and of these feasts is very widely spread amongst savage tribes. The re-burial takes place at different intervals of time, usually at the end of one year from the time of the first burial. The first burial is not the final burial. The soul of the dead, as we saw previously, is driven out of the dwelling-hut with sticks. The body is buried in the village cemetery. The ghost or soul of the dead does not go away to the great village of the dead in the west. It hangs about the cemetery and the village until the second burial at the Feast of the Dead.

To turn to West Africa. We are told that in Calabar the body of the dead is buried within a few days. The burial of the soul, however—the really important matter—does not take place for perhaps a year, because it is an expensive matter, and therefore, the survivors have to wait till they can afford it. The fees for getting it done properly are heavy, and meanwhile the ghost is still about.

I have used the words soul, ghost, spirit indifferently. It is difficult to understand from the words used by savages exactly what their conceptions are. The words used, as the savages often know themselves, are figurative and inexact. Many a traveller has carried away as a sort of joke the story that natives think their shadows are their souls, because they use the word for shadow as a description of the soul. As a rule, such a traveller could

probably not tell what he meant by the word "soul" himself.*

A Huron chief explained (x., 287), to Father Breboeuf, that there were two sorts of souls. One separates itself from the body at death, but remains in the cemetery till the Feast of the Dead, then it changes into a turtle dove or goes away to the Village of the Dead in the West. The Mengwe Indians let loose a bird over the grave to carry off the ghostly self. The other kind of soul, the chief said, is bound to the body and informs the corpse. It remains in the ditch of the dead after the Feast and never leaves it, unless someone bears it again as a child. How else was it that the living resembled the dead? This soul apparently was specially connected with the bones, and hence comes the careful treatment of the bones, whether of human beings or of animals, as we have already seen.

The Dacotas say that at death everyone is decomposed into four ghostly individualities, of which one flies to the land of shades, the second goes into the air, the third remains in the corpse, the fourth wanders about the village.

In Calabar, too, everyone has four souls—(1) the immortal soul, (2) the shadow in the path, (3) the dream soul, (4) the bush soul. This last is somewhat detached. A perfectly quiet, respectable man may have a most rascally bush soul, which is always getting itself and him into mischief.†

Similarly, the Aruntas in Central Australia split the personality of a human being into different ghostly parts.‡

To turn to a modern instance, it is said that Hartley Coleridge when a boy was once asked, why he was called

* Codrington, *The Melanesians, their Anthropology and Folk-Lore*, p. 248.
† Miss Kingsley, *Travels in West Africa*, p. 460 ff.
‡ Spencer and Gillen, *op. cit.*, p. 515.

Hartley? to which he replied, "which Hartley?" "Why, is there more than one Hartley?" said the questioner. "Yes, there is a deal of Hartleys," replied the boy, "there is picture Hartley and shadow Hartley, and there is echo Hartley and there is catch-me-fast Hartley," seizing his own arm very eagerly. Most of us are not sons of eminent philosophers, and so do not become troubled to this extent by questions of personality and identity, but the difficulties of Hartley Coleridge may serve to illustrate the ideas of savages. With the Hurons, the Jesuits say, the soul had different names according to its different functions, *e.g.*, reason, thought, affection. (x., 141.) Over and above this was the difficulty of explaining its nature after death.

I said just now that there were two feelings in regard to the spirits of the dead—fear of the ghost and desire to maintain the bond of union with the kindred dead. According to the varying intensity of these feelings we find variation of burial practices or funeral rites. There is a wide difference between the negroes of the Niger Delta, who bury their dead under the floor of their huts,* and the Kaffirs, who throw the body out into the bush before the life has well departed. Sanctity, it has been said, is a polar force; it both attracts and repels. An analogy has been drawn between the treatment of the dead and the treatment of sacrifices.† How dispose of the kindred dead? How dispose of sacrifice?

1. Sometimes the whole of the sacrificial victim was eaten. Nothing was left. Similarly, Herodotus‡ tells us of a tribe who killed and ate up their relatives as they grew old. A less repulsive practice is that of the

* Cf. Plato, *Minos*, 315 D, and *Classical Review*, xi., 33 ff., for discussion of such hut burial in ancient Rome.

† Robertson Smith, *op. cit.* pp. 356, 369.

‡ Hdt., i., 216, cf. also iv., 26.

Arawaks of South America, whose wives are said to dry the bones of their dead husbands, reduce them to powder, make an infusion and drink the mixture. The dead were eaten possibly to keep the soul in the family, just as at the death of an ancient Roman the nearest kinsman leant over to inhale the last breath of the dying, or as Algonkin mothers flocked to the side of the dying in the hope of receiving the passing soul.

2. The sacrifice was not eaten, it was flung away in a desert place outside inhabited districts. Similarly, there are tribes, as for instance in South Africa, who take the dead away from their habitation, and leave the bodies exposed to wild beasts. We may compare the towers of silence of the Parsees and the practice of the ancient Magi,* but in these cases there is the further notion that earth, fire and water are not to be defiled by contact with putrefying flesh.

3. Lastly, where the sacrifice was not eaten, it or the part of it which was not eaten was burnt or buried. Similarly, in the case of dead bodies we have inhumation and cremation. The corpse, like the sacrifice, is "taboo," a source, that is, of very dangerous supernatural influences of an infectious kind.

I have not gone through all forms of burial. Besides inhumation, whether in graves, caves, mounds, &c., there is embalment, as with the Egyptians and Chinese, urn burial, burial in trees and burial in water. In a great many instances, with savages in different parts of the world, there is a second burial. There seems to have been a wide-spread wish to get rid of the perishable part of the body before the final disposal of the remains and laying of the ghost. Various means are

* Hdt., i., 140.

employed. For instance, on the banks of the Orinoco, there is a tribe which ties the bodies of the dead to the roots of trees and lets them drift on the river till the fish have cleaned the bones. Then they take the bones out and keep them in their huts. In Hyrcania a breed of dogs was kept at the public expense to serve as sepulchres.* But whether animals, earth, fire, air, water, or embalming were the agency employed, the object seems to have been to prevent putrefaction or to remove its consequences.

Cremation has been held to imply a different theory of future life from that implied in burial. In the case of burial, it is said, the soul remains in the tomb. Offerings of food are brought to the tomb, and sometimes a means of communication was left from the outside to the inside of the grave for the passage of food.† To get hold of the remains of a famous hero is to secure the help of his spirit. The Spartans got hold of the bones of Orestes, the Athenians of the bones of Theseus. In West Africa great efforts are made to secure the skulls of famous chiefs, and it is necessary to conceal their graves with care for fear the enemy should carry them off.

Cremation, on the other hand, is held to imply that the spirits of the dead go away to another world and return no more.‡ As in sacrifice fire conveys the material object to the gods, so fire translates the soul from the material to the immaterial world. Or else it is that, as fire etherialises the sacrifice, so, by burning, the body is etherialised and enabled to join the soul. Certainly, no gift could go with the soul of the cremated person unless it also was burnt. The wife of the tyrant of Corinth came back to complain that her clothes had not been burnt

* Ridgway, *The Early Age of Greece*, p. 487.

† Ridgway, *op. cit.*, p. 510.

‡ Hom., *Il.*, xxiii., 69 . . *Od.*, xi., 51

with her body, and to bury them in the tomb unburnt was of no manner of use.*

We do not know when or where cremation first originated. We find both practices at different periods in the history of the same people: we also find both practices going on simultaneously in the same people. In ancient Greece, burial was the practice of the Mycenean age, as the tombs described prove. In the poems of Homer, cremation is the mode of disposing of the dead.† Later on, burial again became the general rule. Cremation was no doubt expensive. Professor Ridgway has recently argued that the Achaeans of the Homeric age were of a different race from the native Greeks,—one of the fair-haired marauding tribes of Central Europe, who conquered and settled down in Greece, and brought the practice of cremation and belief in another world amongst a population which practised burial, and believed that the spirits of the dead remained in the tomb. Still, the Achaeans in Homer may have burned their dead for special reasons. Pliny‡ suggests that burning was adopted in the case of Rome because the bodies of those who died and were buried in foreign wars were sometimes disinterred. The Greeks of the Homeric age were on foreign service. They could not send their dead home, and to bury them in foreign soil might leave them exposed to insult. The Mengwes of North America burned the bodies of those who died on the field of battle and collected the ashes, just as the Achaeans in the Homeric age did. The Hurons burned the bodies and brought home the bones of those who died out of their own country. We are also told that the souls of those who died in war formed a

* Hdt., v., 92.

† The word ταρχύειν in Homer may be a relic of a process of embalming.

‡ *Nat. Hist.*, vii., 187.

band by themselves in the Village of the Dead in the West. The other souls were afraid of them. At Rome, burial was the older practice, and when burning was adopted as a general practice, some families preferred inhumation. The dictator Sulla was the first of the great Cornelian *gens* to be burned in the funeral pyre, and this was done in order that his body might not fall into the hands of his deadly enemies the Marians.

Sometimes we find in the same tomb a buried skeleton along with the charred remains of a cremated corpse. Sometimes, as at Myrina, in Asia Minor, and at Hallstatt, in Austria, there are instances of partial cremation where the head, or trunk, or part of the body is burnt and the rest buried.*

In the barrows of this country it is said by Canon Greenwell that no rule can be laid down as to inhumation and cremation. The proportion of burnt to buried remains varies in different districts. Different modes of disposing of the dead can clearly exist side by side. Inconsistent beliefs can also exist at the same time. As in ancient Greece, men can believe in Hades and the Isles of the Blessed, and yet make offerings at the tomb as if it still had a tenant. The beliefs belong to different strata as it were, but are maintained together in spite of their inconsistency.† It is at any rate clear that belief in another world can exist apart from the practice of cremation, as, for instance, in ancient Egypt, where the idea of burning the dead was horrible.‡ The Hurons, too, as we have seen, believed in another world, and tried to account for seeming inconsistences in their beliefs. I have spoken of different treatment of the bodies of those slain

* *Ecole Française d'Athènes*, i., 73, and cf. the curious custom of dealing with the *os resectum* at Rome, Cic. de Legg. ii., 22, 57.

† Gardner, *Sculptured Tombs of Hellas*, p. 45.

‡ Hdt., iii., 16.

in battle. All among the Hurons who died by a violent death were differently interred from other dead. Those who were drowned or died of cold had the flesh torn off their bones, the bones were thrown into a ditch, and were not removed at the Feast of the Dead. Similarly, amongst Greeks, Romans, and Hindus, to take no other instances, we find different modes of burial for such deaths as were caused by suicide, lightning, and drowning. Such deaths are due to the wrath of higher powers.

I dealt earlier in this paper with the practice of the resuscitation of a dead chief by passing on his name to a living man. Father Poncet (xl., 119), after giving an account of the tortures he suffered at the hands of the Iroquois, relates that he was given to an old woman in place of a brother of hers, who had been captured or killed by those on the French side. Upon his entering her cabin, she and her daughters began to sing the song of the dead. "The renewal of mourning for the dead," he says, "caused the departed to become alive in my person." Of other tribes in the north-west it is said that the medicine men pretend to receive the spirit of the dead in their hands, and can transfer it to anyone who takes the name of the dead in addition to his own (xvii., 243[n]). Just now we saw that a Huron chief believed that the reason the living resembled the dead was that souls of a certain kind were born again. In the Niger Delta no one's soul dallies below long. The soul's return to its own family is insured by special ju-jus (charms). As the new babies arrive, they are shown a selection of small articles belonging to deceased members of the family. The child is identified by the article which first attracts its attention. "Why, he's Uncle John, see! he knows his own pipe," &c.* In the case of children, precautions are taken to render re-birth

* Miss Kingsley, *Travels in West Africa*, p. 493.

easier. Father Breboeuf says that the Hurons had special ceremonies for the burial of little children who die less than a month or two old. The bodies were interred on the road or pathway in order that they might secretly enter the womb of any passing woman and be born again. In West Africa, too, Miss Kingsley says that the bodies of little children are thrown near the path in order that their souls may choose a new mother from the women who pass by.* In Central Australia we are told that there is a round stone with a hole on one side through which the spirit children are supposed to be on the look-out for women who may chance to pass near, and it is firmly believed that a visit to this stone will result in conception. A woman who wishes a child will go to the stone; a woman who does not wish will wrap her head up when she passes.† Other instances amongst savages could be given. Coming to more civilised nations, we find that in ancient Rome the bodies of children who had not cut their teeth were buried, not burnt.‡ There is also a statement coming from a late authority, Fulgentius, that infants were buried under the eaves.§ The Hindus, who practice cremation, do not burn the bodies of infants; they bury them if they are under two years of age, or unless they have cut all their teeth. In the case of Rome, the ancient ritual or custom survived after the belief had disappeared.

The savage notion has been given fully in recent accounts of the Central Australian tribes. With them there are certain totem centres connected with different localities. The child belongs to the totem associated with the locality in which the mother was at the time of

* Miss Kingsley, *op. cit.*, p. 478.

† Spencer and Gillen, *op. cit.*, p. 337.

‡ Pliny, *Nat. Hist.*, vii., 72—Juv. xv., 140.

§ cf. *Classical Review*, xi., 33 ff.

conception, not at the time of birth. For instance, an Emu mother conceived when she was in the locality of the Witchetty grub totem. The child was born 100 miles off in the Emu territory, but all the same it counted as a Witchetty grub.* Time after time these natives have been questioned, and have asserted their belief that children are not the direct result of human intercourse. Now we have an ancient Greek law, found in the island of Ceos, regulating funeral rites. Amongst other regulations of interest, it directs that no woman is to enter the room from which the corpse has just been taken unless she is the daughter of a cousin of the deceased, or a still nearer relation, such as mother, daughter, sister, &c. Similarly, we have a law of Solon's quoted, which forbids any woman under 60 to enter the chamber of the deceased or follow the corpse to the tomb unless she is a cousin's daughter or still nearer relation.† The soul after death was a shadowy, weakly thing; it could be entangled in the sweepings of the room, it went at the head of the funeral procession to the grave. (x., 143.) It is a legitimate inference, then, to suppose that in these regulations we have survivals of a primitive belief in the re-birth of the soul, and the object of the regulations was to ensure that the soul should be born of a woman belonging to the family of the deceased. At Rome, if a man, supposed to be dead, returned home, he was let in through the roof. In Greece we are told by Plutarch that, if a man had been given up for dead, and his funeral solemnised or prepared, and then he recovered, he was solemnly committed as an infant new-born unto women for to be washed, to be wrapped in swaddling clothes, and to be suckled. His soul had got back at once into its

* Spencer and Gillen, *op. cit.*, p. 124, 265.

† Rœhl, *Inscr. Antiquiss.*, No. 395, Dem. *c. Macart.* § 62.

former habitation, and logic required that in spite of any appearances to the contrary he must begin life again. These instances are enough to show that the idea of re-birth was widespread, and many more instances could be given where the burial rites observed in the case of young children are different from the rites observed in the case of adults.

It must be admitted that, though the burial rites of children are so often of a special character, the belief with reference to their souls is not always the same. The reason given why Hindus do not burn the bodies of infants is that, if they did so, the spirits would become malevolent demons. They bury them, therefore, that the spirits may be kept near the body and propitiated with offerings.* Amongst the Maoris of New Zealand there is a belief that disease is specially caused by the spirit of an infant or undeveloped human being.† Perhaps one might add here the mediæval superstition that, if an infant died unbaptised, it was necessary to drive a stake through the body at burial to prevent its spirit from giving trouble.

As a rule, however, the spirit of an infant child is regarded as an object of pity, because it must be so helpless. The Hurons thought that the souls of little children were not strong enough to take the journey to the Village in the West.‡ The Eskimos put a dog's head upon the tomb of a child, because a dog can find its way anywhere and can,

* Ridgway, *op. cit.*, p. 532.

† Tylor, *Prim. Culture*, ii., 127.

‡ "The souls go away in company covered as they are with robes and collars which have been put into the grave for them, to a great Village which is toward the Setting Sun—except, however, the old people and the little children who have not as strong limbs as the others to make this voyage; these remain in the country, where they have their own particular Villages." (x., 143.)

therefore, help the child. A tribe of Melanesians, when a favourite child dies, sacrifice the mother's aunt or the grandmother to go and look after it. The same idea leading to a different practice is shown when the Papuans and Bushmen kill a sucking child if its mother dies. A case is quoted where a Huron child was buried alive with its dead mother from motives of compassion. An account of the Abnakis of North America states that they are inconsolable at the death of a child—believing that it was wretched in the other world because it was too young to look after itself and too weak to procure the necessaries of life.

When such are the notions held by savages it is hard to see how they can be reconciled with the practice of infanticide which is so frequent amongst savage tribes. Infanticide, we are told, is often not regarded as murder if it be performed immediately after birth, but, according to the views we have been considering, infanticide would have the effect of preventing a family relation from coming back to life. The question of infanticide is a practical one.* Savages suckle their infants for a long time, often for three or more years. How can the mother provide food enough for the newborn infant and for the next youngest as well—how provide food for twins? Amongst the Aruntas of Central Australia the infant is killed immediately after birth. The spirit part of the child goes back to the place from which it came, and can be born subsequently of the same woman.† Even apart from infanticide, deaths of children are very frequent amongst uncivilised people, and by the Jesuits it was

* Another practical question was the treatment of the old. The Indian tribes deserted or even killed the agèd or infirm, thinking that they were thus doing them a good service, for otherwise they would be compelled to die of hunger. (iv., 199.) "These people being nomadic cannot drag after them their fathers or friends, the aged or the sick." (ii., 151.)

† Spencer and Gillen, *op. cit.*, p. 51.

calculated that scarce one in thirty survived to grow up. Re-birth is easy, and is often rendered easier by burial of the bodies of children in frequented places, by the pathways, and in or at any rate near the dwelling hut. We have quoted instances of burial by the paths. In Cumberland Valley, Tennessee, there were found 70 houses in an ancient village. Under the floors of hard clay were found graves of children, one to four in nearly every house, along with pearls, shell beads, and pieces of pottery for them to play with. In the burial mound of the village only the remains of adults were found.* In the lake village at Glastonbury, Somerset, which is held to date from the time just preceding the Roman conquest of Britain, the bones of a young child were found in the floor of a dwelling near the hearth, and there were other remains of children found in various parts of the village. Besides these, there were two or three skulls of adults—one with a sword-cut—but these may have been trophy skulls hung up in the huts, or may be otherwise accounted for. No other bones of adults have been found. So far as the evidence goes it points to hut burial for infants. Similar burial might be quoted from the Solomon Islands and elsewhere. Professor Petrie, in his account of his explorations at Kahun belonging to the XIIth dynasty, says, "In many of the rooms there were burials of objects in the floor. Many boxes were found in which babies had been buried. The boxes were evidently intended for domestic uses, but babies were put in them, sometimes two or three together, and buried in the rooms. The infants were often some months old." In reference to Egypt, we must of course remember that the Egyptians also kept their mummified adult relatives in their houses.

In general, we may say that there is a good deal of evidence that, in different parts of the world and among

* First Report of the Bureau of American Ethnology, 1879-1880, p. 116.

races of various degrees of civilisation, there was a different mode of burial for infants as distinguished from adults. There is, however, a wide severance of feeling between the Hindu and Maori, who look on the spirits of infants as especially dangerous, and the Red Indian who regards them as helpless and deserving of pity. But, as we have seen, beliefs which in their origin resemble one another work out in different directions. Lucian said, "The Greek burns, the Indian covers in crystal, the Scythian eats, the Egyptian embalms," and yet there is a great similarity between their ideas about the dead and their relation to the living. Take the treatment of twins. In parts of West Africa the birth of twins is regarded with horror. The children are killed and the mother disgraced, and the natives will not give their reason. In other villages, however, we are told that the birth of twins is an event to be celebrated with joy and festivity. The Peruvians worshipped twins as supernatural beings, and amongst other natives we find different practices in regard to what is looked upon as an extraordinary occurrence.

Having now dealt with the different matters in these volumes of the Jesuit Relations to which I wished to call attention, I will conclude by quoting what was said in 1612 by Lescarbots, a Huguenot settler, which seems to be a remarkable anticipation of a more modern attitude towards primitive custom and belief.

"You cannot all at once eradicate the deep-rooted customs and habits of any people, whoever they may be. The Apostles did not do it, neither was it done several centuries after them. Witness the ceremonies of the candles on Candlemas—the processions of the Rogation days—the bonfires of St. John the Baptist's day, the holy water and many other traditions that we have in the Church, which have been introduced for a laudable purpose to convert to a good usage what had only been abused.

XIV. On the Atomic Weights and Classification of the Elementary Gases, Neon, Argon, Krypton, and Xenon.

By HENRY WILDE, D.Sc., F.R.S.

Received and read April 15th, 1902.

In a note which I presented to the French Academy of Sciences in 1897 (*Comptes Rendus*, Tome 125, pp. 649, 707), the position of argon in my classification and Table of the elements,* was the next higher member of the series H7n to nitrogen, with an atomic weight equal to 21. Helium was also shown to be the typical element at the head of the positive series H2n, with an atomic weight equal to 2. This number is now adopted in the Table of atomic weights published in the *Annuaire du Bureau des Longitudes*, as also the experimental atomic weight of argon equal to 20—these values being more rational than the double numbers, 4 and 40, which have been proposed for helium and argon respectively.

The recently discovered elements, neon, krypton and xenon, fully confirm the position and atomic weight of argon in my Table, and the more recent determinations of the densities of the new gases by Professor Ramsay and Dr. Travers† prove conclusively that they also belong to the same series H7n.

* "On the Origin of Elementary Substances, and on some new Relations of their Atomic Weights," *Proc. Lit. and Phil. Soc. Manchester*, Vol. xvii., p. 218, 1878 ; *Manchester Memoirs*, Vol. 30, p. 144, 1887. *Ibid.*, Vol. 39, p. 84, 1895 ; *Chem. News*, Vol. 38 (1878), pp. 66, 96, 107.

† *Phil. Trans.*, Vol. 197, p. 82, 1901.

The densities assigned to these elements, including argon, are :—

Neon.	Argon.	Krypton.	Xenon.
9·96	19·96	40·78	64

M. Berthelot and other chemists have shown that, within the limits of experimental error and residual interferences, argon is one and a half times as dense as nitrogen, and stands in the same relation to this element as ozone does to oxygen, with similar exaltation of their inert and active properties respectively. For the like reasons that determined the density of argon to be 21, the density of krypton is 42, and of xenon 63.

Now as the atomic weights of all elementary gases, at ordinary temperatures, are expressed by the same numbers as those of their densities, the atomic weights of argon, krypton and xenon (21, 42, 63,) form a definite triad like those of the alkaline metals and of several other series of elements. Moreover, these numbers clearly establish the new gases as members of the series H7n, as $3 \times H7 = 21$: $6 \times H7 = 42$: $9 \times H7 = 63$. The multiple numbers 3, 6, 9, also form a triad similar to that of the atomic weights of the three gases.

Although the density of neon is at present anomalous, I have ventured to identify this element as the first member of the series H7n, with an atomic weight equal to 7. The great difficulty experienced in isolating neon from its denser congeners, may probably have prevented the atomic weight of this gas from being more approximately determined.

The members of the series H7n in my table of elements, arranged with their atomic weights in multiple proportions, now stand in the following order :—

	H7n.		
Ne =	$1 \times H7 =$	7.	
N =	$2 \times H7 =$	14.	
Ar =	$3 \times H7 =$	21.	
Kr =	$6 \times H7 =$	42.	
Xe =	$9 \times H7 =$	63.	
Si =	$4 \times H7 =$	28	or $5 \times H7 = 35$.*
Fe =	$8 \times H7 =$	56.	Mn 55. Ni 58. Co 58.
Pd =	$15 \times H7 =$	105.	Pd 105·6. Rh 104·4. Ru 104·4. Da.
Au =	$28 \times H7 =$	196.	Pt 197. Ir 198. Os 198.

The definite multiple relations among the atomic weights of the gaseous members of the series, indicate that they were formed when their constituent parts had considerable freedom of motion. In this respect the gaseous series bears some resemblance to the triads of the alkaline metals and other positive and negative forms of the series Hn, H2n, which, at one period of their history, formed part of the highly heated atmosphere of the terrestrial globe. The resemblance of these several series to each other is further seen in the characteristic spectra of the triads of the new gases (including argon) to the homologous spectra of the triads of the alkaline and alkaline earth metals.

The characteristic inertness in the presence of reagents of the series H7n, including iron under peculiar conditions, is referred to in my paper on the origin of elementary substances. It is also therein suggested that the members of the iron, palladium and platinum groups of metals are, respectively, allotropic varieties of each other, and that "it is no objection to the theory that these metals cannot by any known power of analysis be resolved into their primaries, as the same objection would apply to the

* Regnault, *Annales de Chimie et de Physique*, Tome 63, pp. 24—31, 1861.

natural varieties of organic species determined by naturalists."

It is not a little remarkable that, while the laws of chemical combination and of crystallisation are established on strictly mathematical bases, the multiple proportions of the elements among themselves have not, so far, been placed on a similar foundation, for the reason, principally, that some of the experimental atomic weights are not whole numbers.

Now the constancy of the angles in crystals of the same substance is considered to be a fundamental law of crystallisation. I have found, however, by exact measurements with the goniometer, that small differences exist in the angles of apparently perfect cubical crystals of fluorite (amounting in some specimens to more than one degree), analogous to those observed among the atomic weights. Similar small differences may also be observed in the angles of other forms of crystals. Such residual interferences, arising from known and unknown causes, would rightly, not be admitted by mineralogists as invalidating the general laws of crystallisation.

ADDENDUM.

It is a common error to assume that discoverers in various departments of science are, necessarily, authorities on the co-ordination of the subject of their discoveries with the general properties of bodies, and with the real nature of things. Thus (1) Berzelius assigned to silicium an atomic weight equal to 21, while the accepted number is 28. Regnault has, however, pointed out that the atomic weight of this element should be 35, in order that it may enter into the law of the atomic heat of other elements. (2) Peligot adopted 120 as the atomic weight

of uranium, and Stromeyer 56 for cadmium, the modern determinations for these elements being 240 and 112 respectively. (3) Scheele's oxymuriatic acid was shown by Davy to be elementary chlorine. (4) Crookes classified thallium with the sulphur group and, subsequently, with mercury, while it has since been proved by others to belong to the group represented by scandium, gallium and indium, as shown in my Tables. (5) Platinum was identified by its Brazilian discoverer with silver and derived its name from that metal. Many similar instances may be adduced from other departments of the natural sciences. It will be sufficient to mention in this connexion, the discovery and first appearance of Saturn's rings, the supposed cometary nature of the planet Uranus, and the landfall of Columbus.

Table of Elementary –1894—1902.

	+ H*n* —		H7*n*	
1	H = 1		Ne = 7	
2	Li = 7 .. .. 7* 0·59†		N = 14 Ar = 21 Kr = 42 Xe = 63	
3	Na = 23 .. .. 23 0·98	F = 19 19	Si = 35 28 : 35 2·49	
4	K = 39 .. .. 39 0·86	Cl = 35 .. .. 35·3·4 1·3	Fe = 56 Mn = 56 Ni = 56 Co = 56	56—8·14‖ 55—8·00 58—8·66 58—8·96
5	Cu = 62 .. .. 63·3 8·9			
6	Rb = 85 .. .. 85 1·52	Br = 81 .. .. 80 3·0		
7	Ag = 108 .. .. 108 10·6		Pd = 105 Rh = 105 Ru = 105 Da = 105	105·6—12·0 104·4—11·2 104·4—11·4 ... ...
8	Cs = 131 .. .. 132 1·88	I = 127 .. .. 127 4·95		
9	*x* = 154 .. .. .. 12·2			
10	*x* = 177 2·2		Au = 196 Pt = 196 Ir = 196 Os = 196	196—19·34 197—21·50 198—22·42 198—22·48
11	Hg = 200 .. .. 200 13·6			

*Accepted Atomiosited.

*** The accepted atomic weights , F. W. Clarke, and Watts'

Table of Elementary Substances, with their Atomic Weights in Multiple Proportions, 1878—1894—1902

	+ H*n* —		+ H2*n* —		H3*n*	H4*n*	H5*n*	H6*n*	H7*n*	
1	H = 1		He 2						Ne = 7	
2	Li = 7 7[illegible] 0·59†		Gl = 8 9·2 1 64? 1 3‡		C = 12 12 1·71§	— = 16	B = 10 11 2 63	— = 18	N = 14 Ar = 21 Kr = 42 Xe = 63	
3	Na = 23 23 0·98	F = 19 19	Mg = 24 24 1·74	O = 16 16	Al = 27 27 2·56	— = 32	P = 30 31 1·82	— = 36	Si = 35 28 : 35 2·49	
4	K = 39 39 0·86	Cl = 35 35 5 1·3	Ca = 40 40 1·58	S = 32 32 2·05	Sc = 42 44 3·4	Ti = 48 48 4·1‡	V = 50 51·2 5·5	Cr = 54 52·4 7 3	Fe = 56 Mn = 56 Ni = 56 Co = 56	56—8·14‖ 55—8·00 58—8·66 58—8·96
5	Cu = 62 63·3 8 9		Zn 64 65 7·2		Ce = 69 92 : 141 6·5	Ge = 72 72·7 5·47	As = 75 75 5·63			
6	Rb = 85 85 1·52	Br = 81 80 3·0	Sr = 88 87 5 2·54	Se = 80 79·4 4·8	Ga = 96 70 5·95	Zr = 92 90 4 15? 5·4‡	Nb = 95 94 6 67	Mo = 96 96 8·6		
7	Ag = 108 108 10·6		Cd = 112 112 8·69		Y = 123 61·7 . 89 5 8·1‡	Sn = 116 116 7·29	Sb = 120 120 6·72		Pd = 105 Rh = 105 Ru = 105 Da = 105	105·6—12 0 104 4—11·2 104·4—11·4 ..
8	Cs = 131 132 1·88	I = 127 127 4·95	Ba = 136 137 3 75	Te = 128 128 6·3	In = 150 75·6 : 113·4 7 42	La = 140 139 6·7	*x* = 140 8·15	*x* = 144 10·0		
9	*x* = 154 12·2		*x* 160 10·13		Er = 177 170 6 9·4‡	*x* = 164 9 11	*x* = 165 8·30‡			
10	*x* = 177 2·2		*x* = 184 4·8		Tl = 204 204 11·85	D = 188 95 8 0‡	Ta = 185 182 10 78? 9·8‡	W = 186 184 18·26	Au = 196 Pt = 196 Ir = 196 Os = 196	196—19·34 197—21·50 198—22·42 198—22·48
11	Hg = 200 200 13·6		Pb = 208 207 11·44		Th = 231 231 4 11·23	U = 240 240 18·4	Bi = 210 210 9·83			

*Accepted Atomic Weights. †Specific Gravities. ‡Estimated. §Anthracite. ‖Electro-deposited.

, The accepted atomic weights are taken from the standard works and tables of Wurtz, Roscoe and Schorlemmer, J. P. Cooke, F. W. Clarke, and Watts' "Dict. Chem. Supp.," p. 247—Atomicity.

Manchester Memoirs, Vol. xlvi. (1902), *No.* **15.**

XV. On the Conditions which render definite the Rate of Propagation of an Earth-Tremor.

By R. F. GWYTHER, M.A.

Received and read March 18th, 1902.

In a paper "On waves propagated along the plane surface of an elastic solid,"* Lord Rayleigh has demonstrated that, if the amplitude of the displacement diminishes with increasing depth according to the simple exponential law, the rate of propagation is definite and unique. It was to trace, if possible, the exact mathematical condition which enforces this unique definite rate that the work of this paper was undertaken, and the result is to connect it with the absence of infinities from the possible forms of solution, and the consequent absence of discontinuities in the stresses either within the substance of the earth or upon its surface.

Taking the surface of the earth as the plane of xy, the solutions of the equations of its motion as an elastic solid lying on the positive side of this plane are to be sought, subject to the conditions that the stress at the free plane shall vanish.

The method which I employ, and which appears to present in an advantageous form the conditions which are to be satisfied when one of the co-ordinate surfaces is a free surface, is to write for the components of the displacement

* *Proc. Lond. Math. Soc.*, xvii., 1885.

$$u = \frac{\partial}{\partial x}(F + f_2 + f_3 - f_1),$$

$$v = \frac{\partial}{\partial y}(F + f_3 + f_1 - f_2),$$

$$w = \frac{\partial}{\partial z}(F + f_1 + f_2 - f_3) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

so that the components of the rotations take the form

$$\frac{\partial^2}{\partial y \partial z}(f_2 - f_3), \text{ etc },$$

and the tangential shearing stresses the form

$$2\mu \frac{\partial^2}{\partial y \partial z}(F + f_1), \text{ etc.}$$

The equations of motion are then satisfied, provided that

$$\{(\lambda + 2\mu)\Delta^2 - \rho d^2/dt^2\} F = \text{constant},$$

$$\{\mu \Delta^2 - \rho d^2/dt^2\} f = \text{constant},$$

and

$$\frac{\partial^2}{\partial x^2}(f_2 + f_3 - f_1) + \frac{\partial^2}{\partial y^2}\{f_3 + f_1 - f_2\} + \frac{\partial^2}{\partial z^2}\{f_1 + f_2 - f_3\} = \text{constant} \quad (2).$$

I shall suppose that the constants in these equations are usually null, and have other than null values only over certain definite areas. For the limited purpose of this paper, it is only contemplated they have other than null values at definite areas near the free surface. It is plain that this introduces potential functions somewhat after the manner of M. Boussinesq's solutions.

Besides the dynamical solutions with which we are principally dealing, there are also statical solutions which are separate, and may be different in character, and which are communicated or removed instantaneously and not by a finite time-propagation. We may instance M. Boussinesq's first type of simple solution, for which I find

$$F = \frac{\mu}{\lambda + \mu} \frac{z}{r},$$

$$f_1 = f_2 = \frac{\lambda + 2\mu}{\lambda + \mu}\left\{\log(r + z) - \frac{z}{r}\right\},$$

$$f_3 = -\frac{\lambda + 2\mu}{\lambda + \mu} \frac{z}{r},$$

where

$$r^2 = x^2 + y^2 + z^2.$$

These statical elastic solutions are not more easy of mental conception than is the rigid dynamical description of an impact between bodies, and I shall omit their consideration in what follows. Also I do not concern myself with standing oscillations which do not depart greatly from a form of possible equilibrium displacement, but confine the investigation to those modes of displacement which are capable of regular progressive transmission.

Writing

$$\lambda + 2\mu = \rho k^2, \text{ and } \mu = \rho h^2,$$

we notice that any solution of $\Delta^2\phi = 0$ or constant, can be made to give a suitable value for F or f, by introducing kt or ht in a proper manner. Thus, if

$$\phi\{(x - x')\cos a + (y - y')\sin a + iz\}$$

is the solution of $\Delta^2\phi = 0$, and we seek a solution suitable for a wave propagated normally into the earth, we should replace z by

$$z\cosh\beta - kt\sinh\beta, \text{ or } z\cosh\gamma - ht\sinh\gamma,$$

it would then be clear that to satisfy the conditions when $z = 0$, we should require

$$k\sinh\beta = h\sinh\gamma,$$

and that we should have two wave-systems travelling with velocities $k\tanh\beta$ and $h\tanh\gamma$ respectively.

If, on the other hand, we desire to represent a progressive surface wave, we should write the amplitude

$$(x - x')\cos a + (y - y')\sin a - kt\,\mathrm{sech}\,\beta + iz\tanh\beta,$$

or

$$(x - x')\cos a + (y - y')\sin a - ht\,\mathrm{sech}\,\gamma + iz\tanh\gamma,$$

and the waves would, to satisfy the surface-conditions, usually combine into one compound system travelling at the rate

$$q = k\,\mathrm{sech}\,\beta = h\,\mathrm{sech}\,\gamma.$$

If a solution has the form

$$\log\{(x-x')\cos a+(y-y')\sin a+iz\}$$

or

$$\{(x-x')\cos a+(y-y')\sin a+iz\}^{-1},$$

etc., it gives rise to infinities along the line

$$(x-x')\cos a+(y-y')\sin a=0$$

in the free surface.

Since we are really only concerned with real values of the displacements, I shall consider that ϕ (and therefore F and f) are expressed in the form

$$a[\phi(U+iV)+\phi(U-iV)]+b[\phi'(U+iV)-\phi'(U-iV)]/i.$$

If we consider now

$$\log\{(x-x')\cos a+(y-y')\sin a+iz\} \\ +\log\{(x-x')\cos a+(y-y')\sin a-iz\},$$

and by integration adapt this for cylindrical polars, we obtain

$$\log\{z+\sqrt{r^2+z^2}\},$$

where

$$r^2=(x-x')^2+(y-y')^2.$$

While differentiation with regard to z leads to the form $(r^2+z^2)^{-\frac{1}{2}}$, and so on.

Analogy with M. Boussinesq's conclusions indicate that infinities arising in this manner are not necessarily to be excluded, but that they may only be admitted in special forms.

The form of wave most likely to be represented in this manner is a form which can travel alone, but if a single pole of any character can be shown to lead to results satisfying the conditions, we can introduce such poles periodically and obtain solutions of the form

$$\log\tan\{(x-x')\cos a+(y-y')\sin a+iz\} \\ +\log\tan\{(x-x')\cos a+(y-y')\sin a-iz\}.$$

CONSIDERATION OF THE ACTUAL PROBLEM PROPOSED.

In the case of progressive surface waves in the question which we are to consider, I shall write

$$F = a[F(U+iV) + F(U-iV)] + b[F'(U+iV) - F'(U-iV)]/i$$
$$f_1 = a_1[F(u+iv) + F(u-iv)] + b_1[F'(u+iv) - F'(u-iv)]/i \quad . \quad (3)$$

etc., where $U+iV$ stands for

$$(x-x')\cos\alpha + (y-y')\sin\alpha - kt\,\text{sech}\beta + iz\tanh\beta,$$

and $u+iv$ for

$$(x-x')\cos\alpha + (y-y')\sin\alpha - kt\,\text{sech}\gamma + iz\tanh\gamma.$$

I shall take it to be an essential condition that the amplitude shall diminish asymptotically to zero as the depth increases.

The condition, generally, that the stresses on the free face shall be null, requires that

$$S \equiv 2\mu\frac{\partial^2}{\partial y\partial z}(F+f_1),$$

$$T \equiv 2\mu\frac{\partial^2}{\partial x\partial z}(F+f_2),$$

and

$$R \equiv \left[(\lambda+2\mu)\frac{\partial^2}{\partial z^2} + \lambda\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\right]F + 2\mu\frac{\partial^2}{\partial z^2}(f_1+f_2-f_3) \quad . \quad (4)$$

shall all vanish, when $z=0$.

In order to satisfy any such conditions, it will be requisite, in the first place, that

$$k\,\text{sech}\beta = h\,\text{sech}\gamma = q \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

where q is the common rate of propagation of the compounded waves.

There may, of course, be solutions into which the F functions only enter, and solutions into which the f functions only enter, as well as those with which we are mainly concerned in which both functions occur, and in which the presence of both sets of functions is necessary to satisfy the surface conditions.

I shall proceed with the case of the compound wave; since we can, from the results, infer the conditions for the simple cases by neglecting (5).

The general condition (2) requires that

$$a_3 = a_1 + a_2 - \frac{2(a_1\sin^2\alpha + a_2\cos^2\alpha)}{1 + \tanh^2\gamma},$$

$$b_3 = b_1 + b_2 - \frac{2(b_1\sin^2\alpha + b_2\cos^2\alpha)}{1 + \tanh^2\gamma}, \quad . \quad . \quad . \quad . \quad (6)$$

using (5).

The surface conditions I shall take to be that the surface is free. From $S=0$, $T=0$, when $z=0$, we infer that

$$b\tanh\beta + b_1\tanh\gamma = 0,$$

$$b_2 = b_1.$$

The conditions affecting the b's are now complete, and give

$$b_2 = b_1,$$

$$b_3 = 2b_1\frac{\tanh^2\gamma}{1 + \tanh^2\gamma},$$

$$b = -b_1\coth\beta\tanh\gamma \quad . \quad . \quad . \quad . \quad . \quad . \quad (7).$$

From the condition that $R=0$, when $z=0$, we get

$$\left(1 - \frac{2h^2}{k^2}\cosh^2\beta\right)a + 2(a_3 - a_1 - a_2)\sinh^2\gamma = 0,$$

or

$$a = -\frac{4(a_1\sin^2\alpha + a_2\cos^2\alpha)\tanh^2\gamma}{(1 + \tanh^2\gamma)^2}.$$

To present the conditions affecting the a's in a convenient form, write

$$a_1 = r + p\cot\alpha,$$

$$a_2 = r - p\tan\alpha;$$

then

$$a_3 = 2r\frac{\tanh^2\gamma}{1 + \tanh^2\gamma} + 2p\cot 2\alpha,$$

$$a = -4r\frac{\tanh^2\gamma}{(1 + \tanh^2\gamma)^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8).$$

With these in the compound wave, we are to combine the relations, from (5),

$$k = q\cosh\beta,\ \ h = q\cosh\gamma.$$

We have to consider two special cases of simple waves, which consist of solutions possible with F functions only, or with f functions only. These arise out of the a's only.

The first case is that of a wave of pure strain, often called the sound wave. In this case

$$a_1 = a_2 = a_3 = 0,$$

and we have the condition from (5)

$$2h^2\cosh^2\beta = k^2,$$

giving the rate of propagation $\sqrt{2}h$.

The second case is a rotational wave without condensation, and it requires $a = 0$, or $r = 0$ in (6.).

We therefore have

$$a_1 = p\cot\alpha,$$
$$a_2 = -p\tan\alpha,$$
$$a_3 = 2p\cot 2\alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9).$$

The displacement in this case is in the wave-front and parallel to the Earth's surface, and we have no limitation of the rate of propagation, except that it must be less than h. These waves will be referred to later.

We remain with two kinds of compound waves, that given by the b's in (7), and that given by the a's, after we have removed from (8) the terms in p which have just been considered. These conditions then give

$$a_1 = a_2$$
$$a_3 = \quad 2a_1\frac{\tanh^2\gamma}{1 + \tanh^2\gamma},$$
$$a \ = -4a_1\frac{\tanh^2\gamma}{(1 + \tanh^2\gamma)^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (10),$$

which should be compared with the b relations in (7). Each of these indicates a wave which satisfies the surface-conditions and which may travel at any rate less than h.

Since we have $a_1 = a_2$, and $b_1 = b_2$, we may make a considerable simplification in the components of the displacement in each kind of wave. In the case of the a's, we shall have

$$u = A\frac{\partial}{\partial x}\left\{2F - (1 + \tanh^2\gamma)f\right\},$$

$$v = A\frac{\partial}{\partial y}\left\{2F - (1 + \tanh^2\gamma)f\right\},$$

$$w = A\frac{\partial}{\partial z}\left\{2F - (1 + \coth^2\gamma)f\right\} \quad . \quad . \quad . \quad . \quad (11),$$

where F and f only differ by containing β and γ respectively, and where the form of the function is

$$[F(U+iV)+F(U-iV)].$$

Similarly, in the case of the b's, we shall have

$$u = B\frac{\partial}{\partial x}\left\{\coth\beta\coth\gamma(1 + \tanh^2\gamma)F' - 2f'\right\},$$

$$v = B\frac{\partial}{\partial y}\left\{\coth\beta\coth\gamma(1 + \tanh^2\gamma)F' - 2f'\right\},$$

$$w = B\frac{\partial}{\partial z}\left\{\coth\beta\coth\gamma(1 + \tanh^2\gamma)F' - 2\coth^2\gamma f'\right\} \quad (12),$$

where, again, F' and f' only differ by containing β and γ, but where the form of each function is

$$[F'(U+iV) - F'(U-iV)]/i.$$

The condition that the waves should be surface waves, so that the amplitude diminishes rapidly with increasing depth and tending asymptotically to zero, can be satisfied by a very varied selection of functions, both algebraic and transcendental. We may construct functions which will give for the displacement apparently infinite values either at single detached poles or at a periodic series of poles, either simple or of higher order at the plane of xy. If, however, we are to exclude all such infinities, we are left only with the single case of diminution of amplitude according to the simple exponential law investigated by Lord Rayleigh.

In order to obtain an expression of the form $e^{-mr}\cos mU$, we must combine our functions as

$$[\cos m(U+iV)+\cos m(U-iV)]$$
$$+i[\sin m(U+iV)-\sin m(U-iV)].$$

To see in what cases Lord Rayleigh's result holds good, we notice that, from (7) and (10),

$$\frac{a}{b}=\frac{4\tanh\beta\tanh\gamma}{(1+\tanh^2\gamma)^2}\,\frac{a_1}{b_1},$$

and as the combination now considered is included in the assumption

$$\frac{a}{b}=\frac{a_1}{b_1},$$

we deduce for it the condition

$$4\tanh\beta\tanh\gamma=(1+\tanh^2\gamma)^2\ .\quad .\quad .\quad .\quad (13).$$

On introducing h, k, and q in place of β and γ, this gives

$$k^2q^6-8h^2k^2q^4+8h^4(3k^2-2h^2)q^2-16h^6(k^2-h^2)=0\quad .\quad (14),$$

which is, *mutatis mutandis*, identical with the bicubic in the paper referred to above.

To this result we may give a somewhat simpler appearance by writing $e^{-\phi}$, or $\cosh\phi-\sinh\phi$, for $\tanh\gamma$, and therefore $\cosh^2\phi e^{-\phi}$ for $\tanh\beta$. Then

$$\frac{1}{q^2}=\frac{1-e^{-2\phi}}{k^2}=\frac{1-\cosh^4\phi e^{-2\phi}}{h^2}=\frac{(\cosh^4\phi-1)\epsilon^{-2\phi}}{k^2-h^2}.$$

whence

$$\frac{8(k^2-h^2)}{k^2}=\frac{8(\lambda+\mu)}{\lambda+2\mu}=(3+\cosh 2\phi)(1-\cosh 2\phi+\sinh 2\phi)\ .\ (15),$$

from which 2ϕ, and therefore q, can be found by the aid of Tables, by trial and error and subsequent approximation.

I now revert to the consideration of a single pole, to examine whether a simple case in which discontinuity in the stresses presents itself can still be made to satisfy the conditions of the problem.

In (11), I write

$$F = \log\{X^2 + z^2\tanh^2\beta\},$$
$$f = \log\{X^2 + z^2\tanh^2\gamma\},$$

in which X stands for $x - x' - qt$, and in which a has been put equal to zero, so that the wave progresses in the direction of the axis of x.

Then, for the stresses R and S, we find

$$R = -4\rho q^2 A(2\cosh^2\gamma - 1)\left[\frac{X^2 - z^2\tanh^2\beta}{(X^2 + z^2\tanh^2\beta^2)} - \frac{X^2 - z^2\tanh^2\gamma}{(X^2 + z^2\tanh^2\gamma)^2}\right],$$

$$S = 4\rho q^2 A\cosh^2\gamma Xz\left[\frac{4\tanh^2\beta}{X^2 + z^2\tanh^2\beta)^2} - \frac{(1 + \tanh^2\gamma)^2}{(X^2 + z^2\tanh^2\gamma)^2}\right].$$

Except at the points where $X = 0$, these vanish with z, and have the appearance of becoming infinite when both X and z vanish. But if we imagine the surface loaded with lines of density σ, all parallel to the axis of y, and compare with the second differential coefficients of the logarithmic potentials due to the attraction of these lines, we may, by analogy, find that R and S are finite, but offer discontinuities of the same character as in the similar case of attraction.

Since these expressions are complicated, I will illustrate upon the simplest case of the wave of displacement transverse to the direction of its progression, and parallel to the earth's surface, under the conditions given by (8).

In this case we shall have, for points not quite close to the pole,

$$\begin{aligned} u &= 0 \\ v &= \sigma\epsilon^2\sinh^2\gamma\frac{X}{X^2 + z^2\tanh^2\gamma)} \qquad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \qquad (16) \\ w &= 0. \end{aligned}$$

If we draw in the substance of the earth, one-half of the cylindrical surface of which the equation is

$$X^2 + z^2\tanh^2\gamma = \epsilon^2\sinh^2\gamma,$$

and within this surface suppose that

$$u = 0,$$
$$v = \sigma X \quad \quad \quad (17)$$
$$w = 0,$$

the conditions will be satisfied at points within the cylinder as well as outside it, and the displacements will be continuous at its surface.

At this surface, of which the section is an ellipse having its minor axis horizontal, and the eccentricity equal to sechγ, the stresses will be discontinuous, the differences of the stresses being given by

$$S = -2\sigma\mu\tanh\gamma\sin\theta\cos\theta,$$
$$U = -2\sigma\mu\cos^2\theta,$$

where $X = \epsilon\sinh\gamma\cos\theta$; $z = \epsilon\cosh\gamma\sin\theta$.

As the elliptic curve of discontinuity travels parallel to the surface at the rate q, we shall have a quantity of matter crossing an arc ds of this curve at the rate $\rho q dz$, and receiving an instantaneous change of velocity measured by $-2\sigma q\cos^2\theta$ as it crosses. The rate of change of momentum is therefore $-2\rho\sigma q^2\cos^2\theta dz$ for the element ds in the direction of the axis of y.

The differential stress at the surface of discontinuity at the same element is in the same direction, viz.—

$$(lU + nS)ds$$

where (l, o, n) are the direction cosines of the normal measured inwards, and therefore

$$lds = dz \text{ and } nds = -dz.$$

Hence

$$(lU + nS)ds$$
$$= -2\sigma\mu(\cos^2\theta + \tanh^2\gamma\sin^2\theta)dz,$$
$$= -2\sigma\mu(\text{sech}^2\gamma\cos^2\theta + \tanh^2\gamma)dz,$$
$$= -2\sigma(\rho q^2\cos^2\theta + \mu\tanh^2\gamma)dz,$$

since $\rho q^2 = \mu\,\text{sech}^2\gamma$.

Hence the rate of change of momentum is not balanced by the discontinuity of the stresses, except when $\gamma = 0$, and in this case there is no finite breadth enclosed within the surface of discontinuity, and the conditions implied as underlying this calculation are not satisfied.

We may, then, conclude that the requisite conditions cannot be satisfied at the surface if it encloses an area of finite dimensions.

If, however, we make the further stipulation with regard to the linear dimensions of this area that $2\epsilon \sinh\gamma$ shall be comparable with $q\partial t$, a quantity of the first order of small magnitudes (namely the distance passed over in a small element of time), we can no longer consider the entrance and exit of an element within the surface of discontinuity to take place at separate intervals of time, and may regard the discrepancies on the two occasions as neutralising each other, and in this case we may regard this as a description of a mode in which a force-system causing local perturbations only, when once established, might travel for some distance as a solitary earth-tremor, of which the rate of propagation is proportional to the eccentricity of the ellipse of discontinuity, and therefore not solely dependent upon the elastic constants.

The simple sound wave, travelling at the rate $\sqrt{2h}$, cannot be similarly treated, and in the compound wave, where the discontinuities cannot be confined to a single surface, the difficulties have been found so great as to preclude its further consideration.

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XVI. The Luminous Organs of Pterygioteuthis margaritifera, a Mediterranean Cephalopod.

By WILLIAM E. HOYLE, M.A., F.R.S.E.

Read May 13th. Received May 26th, 1902.

The species which forms the subject of the present communication was created more than half a century ago by Dr. Rüppell, * under the title *Enoploteuthis margaritifera*, and owes its trivial name to its most striking character—a semicircle of pearl-like bodies, surrounding the lower portion of the eyeball. Vérany in 1851 † figured and described it, and two small specimens, apparently referable to the same species, were obtained by the "Challenger" Expedition‡. The form which Dr. Jatta has included under this name in the Naples monograph‖ does not appear to me to be correctly identified.

It is evidently a form of somewhat rare occurrence; there are two specimens in the British Museum from Dr. Rüppell's collection from Messina, perhaps the only locality where it has hitherto been obtained; and as Rüppell's original examples are not, so far as I am aware, in existence, these must be regarded as the types of the species; at all events they have the authenticity of co-types. The species has recently been removed by my friend Dr. Pfeffer ** to the genus *Pterygioteuthis* Fischer, a step which I think quite proper, though it certainly differs specifically from Fischer's type (*P. giardi*), as I hope to show elsewhere.

* *Giorn. Gab. Messina*, vol. 26, p. 2, 1844.

† "Céphalopodes de la Méditerranée," p. 82, pl. 30, 1851.

‡ "Report on the Cephalopoda collected by H.M.S. 'Challenger,'" p. 171, pl. 29, 1886.

‖ "Cefalopodi viventi nel Golfo di Napoli," p. 87, pl. 12, 1896.

** "Synopsis der oegopsiden Cephalopoden," Hamburg, 1900.

I am not aware that any investigation has hitherto been made into the structure of the luminous organs in this species, and as I have recently been fortunate enough to become possessed of a specimen it has appeared worth while to give a brief account of the main features of their organisation. The example at my disposal unfortunately was not in very good condition, so that the observations here recorded will doubtless require extension and correction when more suitable material is available.

The luminous organs of this cephalopod may be divided into four sets :—

I. Ocular.
II. Siphonal.
III. Branchial.
IV. Abdominal.

I. *The Ocular Organs* form a series of warts projecting

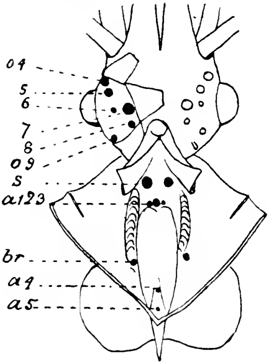

Fig. 1.

Sketch of the ventral aspect showing the position of the luminous organs; natural size. The mouth cavity and siphon have been laid open and the integument covering the eye has been reflected on the right side: *a 1—5*, abdominal; *br*, branchial; *o 4—9*, ocular; *s.*, siphonal organs.

from the surface of the eyeball itself, and arranged, roughly speaking, on its ventral surface; they are thus covered by the skin, and owing to the opacity and shrinking of the tissues caused by the alcohol, they are very rarely distinctly visible in preserved specimens. In the example examined by me there are nine on each eyeball, which are arranged as follows:—There are three on the anterior aspect (*Fig.* 2, *o1*, *o2*, *o3*), arranged in a vertical line on what may be called the equator of the globe; the lowest of these is the largest, measuring about 1·5 mm. in diameter; it projects as a lenticular elevation above the surface. The uppermost is the smallest, measuring 0·6 mm. in diameter; its surface is elevated into a kind of keel, but I am not quite sure that this shape is a natural condition; it may be due to shrinkage and pressure of the overlying integument.

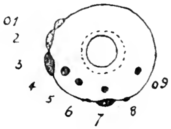

Fig. 2.

Side view of the left eyeball; natural size. *o 1—9.*, ocular organs.

Behind and below this set are two organs, distinctly smaller than the largest of them, situated rather nearer the lens (*Fig.* 1, *Fig.* 2, *o4*, *o5*), and behind these, immediately below the centre of the lens, is another about the same size as the uppermost of the first trio (*Fig.* 1, *Fig.* 2, *o6*). At the lowest point of the globe is another (*o7*), which is nearly as large as the lowermost of the anterior three (1·3 mm. in diameter), directly behind this is the eighth (*o8*), and behind this again and somewhat nearer the

lens is the last of the whole group (*og*). Most of the organs are dull greyish in colour, but some of them have a lustrous appearance, with a play of prismatic colours, and under a lens the surface looks as though divided into a number of facets something like the compound eye of an insect, though, as will be seen from what follows, the resemblance is merely superficial. I have examined sections of several of these and will describe in the first instance the structure of one of the larger ones.

The largest ocular organs are the one directly in front of and the one immediately below the eye; they are spheroidal in form and measure, rather more than 1 mm. in diameter. As regards structure, each may be divided into the following parts :—

1. The Capsule.
2. The Posterior Cup.
3. The Inner Cup.
4. The Central Mass.
5. The Internal Cone.
6. The Anterior Cap.

1. The *capsule* (*Fig.* 3, *c.*) is about 0·05 mm. thick, and consists of connective tissue : in the outer layer are fibres and cells intermixed, whilst the deeper layer consists almost entirely of fibres disposed parallel to the surface. Towards the equator of the organ this layer becomes somewhat thicker and gradually merges into the loose areolar connective tissue in which the organ is embedded. Outside the capsule is a membrane composed of a single layer of columnar cells, with spheroidal nuclei (*Fig.* 3, *b.*), which has the appearance of parenchymatous cartilage and is, doubtless, the exterior layer of the eyeball seen in section.

2. The *posterior cup* (*Fig.* 3, *p.c.*) is of very remarkable appearance : in a median section of the organ it is seen to

consist of a large number of scales of fusiform or concentric outline, which are disposed roughly speaking in concentric layers forming a kind of cup, in which the central mass is lodged. Tangential sections show these to be rounded scales, under which name, as it implies no theory as to their function, we may conveniently speak of

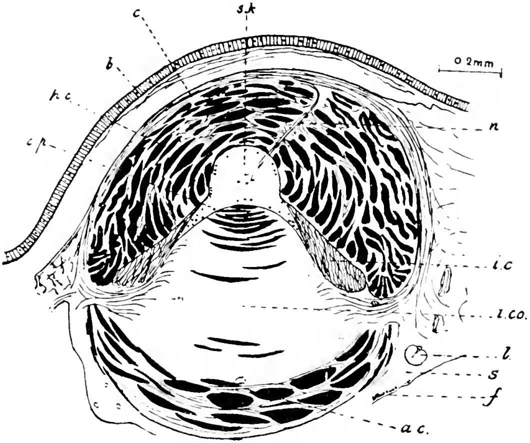

Fig. 3.

Median section of one of the large ocular organs: *a.c.*, anterior cap; *b.*, basal layer of cartilage; *c*, connective tissue capsule; *c.p.*, conical projection of central mass; *f.*, round bodies near external surface; *i.c.*, inner cup; *i.co.*, inner cone; *l.*, lacuna; *n.*, nerve; *p.c.*, posterior cup; *s.*, space between the anterior cap and external surface; *s.k.*, spheroidal knob of central mass.

them. In my preparations, stained with hæmatoxylin, these scales are very darkly coloured and stand out in marked contrast to the surrounding tissues. A difference in structure between the inner and the outer cells is at once apparent. The former are much more regular in shape and with much more even outline than the latter;

moreover they do not stain quite so deeply. These inner scales are seen in tangential sections (*Fig.* 4) to be discs

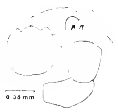

Fig. 4.

A few of the scales from a tangential section of the posterior cup ; *n*, nerve.

of varying shape, recalling flattened epithelial cells. Sometimes they are nearly flat, as in the outer layers; sometimes they are hollowed into a shallow dish-like shape, where they fit round the central spheroid of the cone (*Fig.* 3). They thin out remarkably at their edges, and in some cases the fine lines produced by these thin edges seen in section appear to run very close to the adjoining bodies, but I have not been able to find any instance in which they are actually connected.

The bodies occupying the outer layers of the cup are, as above indicated, distinguished by a deeper coloration, and by more irregular wavy outlines. They are on the whole decidedly thinner, especially in the outer layers nearing the equator of the organ, whilst towards the edge of the cup they lose, to a large extent, their concentric arrangement, and exhibit a tendency to dispose themselves in lines radiating outwards. In internal structure, too, they are much more granular.

As to the nature of these bodies forming the cup I feel some uncertainty ; it seems to me quite clear that they are not cells, for I have been unable to find a nucleus in any of them. It is true that some have a distinct body in the centre, but this has apparently no structure, and it appears to me most likely that they are composed of

chitin or some similar substance of horny consistency, which may have been deposited around such a centre, which would, in this view, be comparable to the minute central cavity seen in the spicules of sponges. In a great many instances these bodies are split and cracked as hard substances might do under the pressure of the razor. The interspaces between these scales are occupied by a delicate connective tissue, which is continuous externally with the inner layer of the external capsule. Here and there the scales are so arranged as to leave passages by which nerve fibres reach the central mass (*Figs.* 3 and 4, *n*).

3. The *inner cup* (*Fig.* 3, *i.c.*) has really the shape of a funnel with an aperture at the bottom through which projects the central knob of the central mass. The funnel is much thickened at the rim and thins away towards the central aperture. The diameter of the funnel is about 0·7 mm. in the largest organs, the depth 0·3 mm., the thickness of the rim 0·1 mm., and the diameter of the aperture at the bottom about 0·15 mm. It is composed of wavy fibres, which stain rather deeply and are disposed for the most part parallel to the inner surface of the funnel.

4. The *central mass* is divisible into two portions, (A) a spheroidal knob, which occupies the centre of the organ (*Fig.* 3, *s.k*), and (B) a conical projection arising from its anterior surface (*Fig.* 3, *c.p.*)

(A) The *central knob* is spheroidal, about 0·15 mm. in diameter, and occupies the hollow space enclosed by the posterior cup above mentioned. It stains but very faintly, and is of a finely granular texture; a few nuclei are scattered in it here and there and are most numerous near the outer surface. The mass of this body is seen to be divided up by a number of fine lines, rather more deeply stained than the general mass, into a number of

roughly rounded constituent parts of varying sizes. The lines of demarcation are more distinct towards the outer surface of the knob.

(B) The *conical projection (c.p.)* arises from the front of the spheroidal knob and passes forwards through the aperture at the bottom of the funnel-like inner cone, and spreads out on its inner surface. In structure it is quite similar to the spheroidal portion, except that in many sections its texture seems to be more open, as though it had given way along the lines of division, and there are rather more nuclei than are found there. It seems to be quite distinctly separated from the inner cup. On its anterior aspect this conical projection is hollowed out so as to receive the back of the internal cone *(Fig.* 3, *i. co.).*

The nerves (*Fig.* 3 *n.*) enter the central knob passing through canals which are left between the scales of the posterior cup ; there is more than one nerve twig supplying each organ, but I have not been able to trace the exact number, nor to ascertain whether it is constant. The nerve fibre is enclosed in a sheath which is continuous with the connective tissue lying between the scales, and here and there along its course a nucleus is fcund lying beside it. Externally I have traced the nerve into the fibrous layer, which forms the outer envelope of the organ. In one or two instances I have been able to trace the nerve entering the central mass. It passes directly inwards and gradually disappears, seeming to give off fibres which pass between the cells of which the central mass is composed. One or two nuclei seem to be present in the continuation of the nerve fibre. The details of the arrangement, however, are not very clear.

5. The *internal cone* occupies the cup formed by the hollow prolongation of the central mass and the funnel-like

inner cup (*Fig.* 3 *i. co.*). It much more than fills this, however, and swells out anteriorly into a rounded elevation, which is surmounted by the anterior cap. As regards its minute structure it consists of a transparent matrix, in which are a large number of very delicate wavy fibres, which have been stained by the hæmatoxylin: they start from the surface of the cone and ramify as they pass inwards, and their general direction is parallel to the external surface, so that they are concave towards the central mass of the organ. The curvature flattens posteriorly but the concavity is never lost.

Elongated nuclei, disposed in the same direction as the fibres, are found here and there among them. At the margin of the posterior cup these fibres are continuous with those forming the capsule of the organ. In the sections they seem, as it were, to flow over the edge of the cup inwards and spread out as they enter it.

In the centre of this inner cone, and more particularly in the deeper portions of it, are seen a number of the scales above described. These, however, are rather thinner than those forming the posterior cup; they are arranged in irregular layers parallel to the course of the fibres among which they lie.

5. The *anterior cap* has the form of a convexo-concave lens with the concavity directed backwards (*Fig.* 3, *a.c.*), and consists of a mass of delicate fibres closely resembling those in the inner cone, in which are embedded a number of scales very much like those above described. They are larger and thicker than those forming the posterior cup, but are not quite so closely placed. There are about four layers of them in the centre, and fewer towards the margins. The fibres constituting the groundwork of this cap are more closely packed than those in the central cone, but except for this and the presence of the lenticular bodies

there is no definite line of demarcation between them. The anterior portion of this cap is rather difficult to make out satisfactorily owing to the defective state of the specimens. In only a few instances is the surface intact, and here it is seen to have the following arrangement. Over the outermost scales is a layer of fibrous tissue, similar to that which lies between them and this again is bounded by a layer of thin deeply stained scales, to all appearance of the same nature as the other. Immediately outside these is a very thin membrane which in its turn is covered by a fibrous tissue, becoming more dense outwards and, as it were, condensing into a definite membrane. Presumably in the living condition this is covered by an epithelium, but no trace of this remains in any of the preparations.

At one side of the organ the external membrane separates from the underlying delicate membrane so that a considerable space, triangular in section, remains between them (*Fig.* 3, *s.*). This is occupied by a delicate fibrous tissue with a good many lacunæ in it. One of these lacunæ is much larger than the others (*l*), and in its neighbourhood are several blood vessels, though it does not seem to have been a vascular sinus itself. Over this thickened part of the anterior cap and lying just within the outermost fibrous layer are a number of deeply stained round bodies (*Fig.* 3, *f.*), which are either nuclei or the sections of fibres.

II. *The Siphonal Organs* (*Fig.* 1, *s.s.*) are two in number, situated just below the hinder margin of the siphon and visible peeping out from beneath it when the mantle is divided in the middle line and laid open. Like the branchial organs, these are in the natural state covered by the mantle, and are only effective by reason of its transparency in the living animal. They are spheroidal

in form, the antero-posterior diameter being the largest and measuring about 1 mm. in length.

In the greater part of its structure the siphonal organ is quite similar to the ocular organs. The only important exception is that over the front of the anterior cap a layer of very remarkable tissue is placed. This consists of rather strong anastomosing fibres, which stain much less deeply than the scales. Near the periphery of the anterior cap (*Fig.* 5, *f.*) arise similar fibres which pass

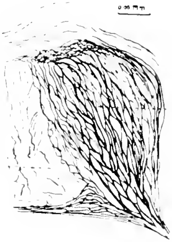

Fig. 5.

Half of the fibrous mass covering the front of the siphonal organ; *f*, mass of anastomosing arborescent fibres; *t.s.*, half the triangular space between the two sets of fibres.

upwards and inwards, ramifying and anastomosing as they go, forming a layer nearly three times as thick as the layer of scales in the anterior cap. There are thus formed in section two arborescent masses, and in the triangular space between them the fibres appear to be somewhat more slender, more irregular, and more.deeply stained (*Fig* 5, *t.s.*).

On that side of the part of the organ, which is directed towards the posterior end of the animal, this tissue gives place to a somewhat different form. This consists of wavy fibres parallel with each other and, roughly speaking, with the axis of the organ. They are somewhat more deeply stained and of a more bluish tinge than the

arborescent fibres just described, though not so deeply as the scales. It appears from a series of frontal sections that this tissue bends round and partly encircles the anterior part of the organ.

Over all this is a fairly thick fibrous layer, but I have not found any traces of an epithelium covering this.

III. *The Branchial Organs* are also paired and situated just at the root of each gill (*Fig.* 1, *br.*). In the female specimen examined they are almost covered, when looked at from the ventral aspect, by the swollen nidamental glands. They measure about 0·75 mm. in the largest diameter; neither in these nor in the siphonal organs did I see under a lens any trace of the lustre observed in some of the ocular group. As regards the minute structure, *Fig. 6* shows a median longitudinal section of the left hand one.

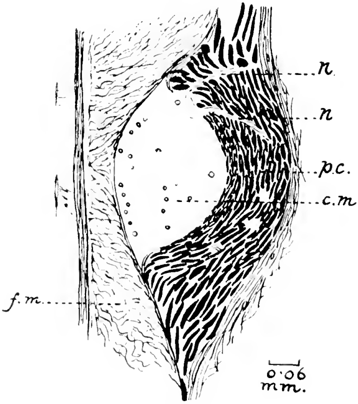

Fig. 6.

Sagittal section of one of the branchial organs; *c.m.*, central mass; *f.m.*, fibrous mass; *n.n.*, nerves; *p.c.*, posterior cup.

The structure of the branchial organs is less complex than that of those previously described. The general shape is more flattened and not so spheroidal, and the hinder part is formed by a cup-shaped mass of scales similar in general to those in the ocular organs, but thinner and much more closely packed, so that there is very little connective tissue between them (*Fig. 6, p.c.*).

The hollow of the cup is occupied by a central mass (*Fig. 6 c.m.*) similar in all essential respects to that in the ocular organs, except that the nuclei seem to be rather more numerous and more evenly distributed. The mass has the form of a very thick double convex lens; three or four nerves pass to it through apertures left between the lenticular bodies forming the cup (*n n.*).

In front of this central mass is a tissue composed of very delicate branching fibres, rising from the surface of the central mass and passing obliquely outwards. They present some resemblance to the fibres constituting the inner cone of the ocular organs, but, whereas these latter are in general parallel to the surface of the organ, the former are nearly perpendicular to it (*f.m.*).

IV. *The Abdominal Organs* are in two groups:—A set of three lying transversely in the mantle cavity (*Fig.* 1. *a 1, 2, 3*) close to the anterior margin of the nidamental gland, the centre one being about 0·7 mm. in diameter and somewhat larger than the lateral ones, and two lying one in front of the other in the posterior end of the mantle cavity in the middle line (*a 4, 5*). These are rather smaller than the lateral ones of the two above mentioned. The sections of these organs were badly broken, doubtless owing to the defective preservation of the specimen, so that it is impossible to give a complete account of their structure. I was able, however, from a careful examination of the fragments to satisfy myself that

they closely resemble the branchial organs in their minute anatomy.

In conclusion, the question may be asked, what evidence is there that these bodies are really luminous organs? The first argument in favour of an affirmative answer is a figure given by Chun of a cephalopod in which the luminosity was actually observed by him on board the "Valdivia,"* and in which the organs so closely resemble in arrangement those above described that one would naturally imagine the two forms to be of the same genus if not the same species. From information given me by Professor Chun, I conclude they must be rather distant systematically. Another argument in favour of the luminous function of these organs is to be found in their structure, which recalls the arrangement described by Joubin, and found by myself in some other forms. Notably is this the case with the bodies I have called "scales" which closely resemble the "mirror-cells" of *Histioteuthis.*†

With respect to the functions of the different parts of the apparatus, I feel no doubt that the central mass is the source of light; its nerve supply obviously suggests this view. The posterior cup I should regard as a reflector and the internal cone and anterior cap as playing the part of lenses.

Finally, I desire to express my indebtedness to Mr. J. T. Wadsworth, of the Owens College Zoological Laboratory, for the sections on which these observations have been made.

* "Aus den Tiefen des Weltmeeres," Jena, 1902.

† Joubin, "Recherches sur l'appareil lumineux d'un céphalopode, *Histioteuthis ruppelii* Vérany," Rennes, 1893, p. 14.

PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

General Meeting, October 1st, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Dr. R. B. WILD, Professor of Materia Medica and Therapeutics, Owens College, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, October 1st, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The donations included the following:—Dr. Schunck's "*The Action of Reagents on the Leaves of Polygonum tinctorium*" (fol., Manchester, 1901), presented by the Author; Dr. Isaac Roberts' "*Photographs of Stars, Star-clusters and Nebulæ,*" Vol. 2 (fol., London, 1899), presented by the Author; "*Opere Matematiche di Francesco Brioschi,*" Tomo 1 (4to., Milano, 1901), presented by the Comitato per le Onoranza a Francesco Brioschi.

The PRESIDENT referred to the loss sustained by the Society through the death of Professor P. G. Tait, one of its honorary members since 1868, and by the resignation of the office of honorary secretary by Professor A. W. Flux, on his acceptance of the Chair of Political Economy in the McGill University, Montreal.

Mr. W. E. HOYLE exhibited two ethnological specimens from Demerara, formerly in the possession of the Manchester Natural History Society under the name of "fish-arrows." They are about 4ft. long, slender, and apparently made from the wall of some hollow reed, with nodes at regular intervals. At one end is a barbed point of wrought iron, the other end being stained a dark brown for about four inches. The use of these weapons is somewhat difficult to determine; they are too thin and flexible either to shoot from a bow or to throw with true aim. Instruments of a similar kind, however, are said to have been used for catching fish by baiting the barbed end and sticking the other end into the bed of the stream among the reeds.

The PRESIDENT communicated a paper on "**The Range of Diotis candidissima Desf., in England and Wales, and in Ireland,**" by Mr. CECIL P. HURST.

General Meeting, October 15th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. J. H. Reynolds, Principal of the Municipal School of Technology, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, October 15th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Attention was drawn to the following donations to the Society's Library:—Christopher Hansteen's "*Untersuchungen über den Magnetismus der Erde*" (4to., Christiania, 1819), presented by Dr. Henry Wilde, F.R.S., and Professor M. Berthelot's "*Les Carbures d'Hydrogène*, 1851-1901. *Recherches expérimentales*" (3 vols., 8vo., Paris, 1901), presented by the Ministère de l'Instruction publique et des Beaux-Arts, Paris.

Mr. R. L. TAYLOR remarked that he had noticed that the Manchester water appeared to contain an unusual amount of dissolved chlorides at the present time, and, on roughly estimating the amount of dissolved solids, he had found that the total had, curiously enough, gone up from a normal amount of about $4\frac{1}{2}$ grains to about $9\frac{1}{2}$ grains per gallon, due, no doubt, to the recent scarcity of water and to the concentration by evaporation on the gathering grounds and in the reservoirs.

Mr. R. D. DARBISHIRE, F.S.A., read a paper entitled: "**On the 'Implements from the Chalk Plateau,' in Kent, their Character and Importance.**"

Mr. DARBISHIRE illustrated with map and section the outline of the denudation of the valley of the Weald, and exhibited a very complete and well-arranged series of the plateau remains.

In the discussion which followed the reading of the paper,

Mr. MARK STIRRUP, F.G.S., referred to the recrudescence of interest in these chipped flints during the last few years, owing to various finds in the chalk districts of the South of England, and to their connection with the theory of the antiquity of man. With regard to one of the cases of exhibits, containing fragments

of flint half-an-inch to one inch in diameter, Mr. STIRRUP said it was doubtful as to what use they could have been put, as they were too small to be handled by man for any practical purpose, The late M. Gabriel Mortillet had suggested that similar fragments were the work of some precursor of man of simian origin, *e.g*, an intelligent anthropoid ape.

Mr. STIRRUP exhibited a work by M. A. Thieullen, containing figures of types of flint implements found in the valley of the Seine, which types resembled in all points most of those exhibited by Mr. Darbishire. Mr. STIRRUP took exception to the use of the term "eolithic" in connection with these Kentish implements, as liable to lead to misconception on the Continent, where the term had been employed for upwards of 20 years to describe implements from the true Tertiary strata.

The PRESIDENT, Mr. HOYLE, and others took part in the discussion.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, October 21st, 1901.

CHARLES BAILEY, F.L., President of the Section, in the Chair.

The PRESIDENT exhibited a foot-length example of a branch of the lace-bark tree (*Lagetta lintearia*, L.) from the West Indies. The woody portion of the stem had been removed, leaving the bark intact at the lower portion of the stem; above that portion, the outermost layers of the bark had been removed, leaving the white bast-layer intact. By soaking the bast in water, the various layers separate from each other like the leaves of a book, and the bast fibres are seen to cross each other as in a woven cloth, or in lace—hence its name of lace-bark or gauze tree. The tree which produces it when fully grown is as thick as a man's leg,

and it grows to the height of thirty or more feet ; there are perhaps twenty or thirty layers of the white bast round the wood. It is common in Jamaica, and the women of the island are very clever in making from it ruffles, caps, and sets of lace, which stand washing. Charles the Second once wore a cravat which had been made from it, and the late Queen Victoria once accepted a bonnet which had been made from the husk of a maize-cob, and the adornments of which came from the white lace-bark of the *Lagetta.* The men make ropes of the same material.

The PRESIDENT also brought a thick native blanket, several yards square, which had been made from the reddish bast of one of the timber trees of the Portuguese possessions in South-East Africa. The tree is cut in lengths ; the outer bark is then removed, leaving the bast-layer exposed; this layer is then slit down, and removed bodily from the wood in the form of a sheet; the sheet is then beaten out with wooden mallets, in which fine grooves have been cut at right angles to each other, so as to form fine teeth. It was called by the natives 'mputa,' but he could give no information as to the tree which produced it. He had looked through the list of useful trees of British Central Africa, drawn up by a native, Harry Kimbiri, and published on pages 227 to 232 of Sir Harry H. Johnston's *British Central Africa* (London, 1897), but could not find it included therein. A tree, producing red bast, from which bark-cloths are made, is given under the name of 'mchile,' or 'Kalisache'; three other native trees are also mentioned as producing bark-cloths and ropes, viz., 'msumbuti,' 'nangwesn,' and 'mjombo,' but the botanical name of the last-mentioned is the only one given, viz., *Brachystegia longifolia.*

The PRESIDENT likewise exhibited specimens of *Diotis candidissima*, Desf., collected by Mr. Cecil P. Hurst in County Wexford, Ireland. A paper by Mr. Hurst on this plant has been lately read before the Society, and will be found *in extenso* in the *Memoirs.*

Extraordinary General Meeting, October 29th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Dr. CHARLES H. LEES was elected an Honorary Secretary of the Society, in succession to Professor A. W. Flux.

Dr. W. J. SINCLAIR, Professor of Obstetrics and Gynæcology at the Owens College; Mr. FRANK F. LAIDLAW, B.A., Demonstrator in Zoology at the Owens College; and Mr. J. E. PETAVEL, B.-ès-Sc., Harling Fellow at the Owens College, were elected ordinary members of the Society.

Ordinary Meeting, October 29th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Attention was drawn to the following donations to the Society's Library:—"*Tychonis Brahe...de Nova Stella*," (4to, Hauniæ, 1901), presented by the Kongeligt Dansk Videnskabernes Selskab; "*Œuvres complètes de Christiaan Huygens*," Tome 9 (4to, La Haye, 1901), presented by the Hollandsche Maatschappij der Wetenschappen; and "*Wissenschaftliche Abhandlungen der Physikalisch-Technischen Reichsanstalt zu Charlottenburg*," Bd. 3 (fol., Berlin, 1900), presented by the Reichsanstalt.

Mr. C. E. STROMEYER read a paper on "**Explosions of Steam Pipes due to Water-hammers.**"

The paper was illustrated by the familiar experiment of shattering a pipe by means of water-hammer, and by reproducing in miniature the waves which are generated in water lodging in long horizontal steam pipes.

Messrs. J. J. Ashworth, E. G. Constantine, J. F. L. Crossland, W. Ingham, M. Longridge, and Dr. Thomson took part in the ensuing discussion.

Mr. EDGAR STANSFIELD, B.Sc., read a paper entitled, "**A Preliminary Note on the Preparation of Barium,**" communicated by Mr. R. S. Hutton, M.Sc.

Extraordinaiy General Meeting, November 12th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Professor F. E. WEISS, B.Sc., F.L.S., was elected a member of the Council.

Mr. A. J. S. BLES, Merchant, Higher Broughton; Miss CAROLINE COIGNOU, Science Mistress at the Manchester High School for Girls; and Miss EDITH M. PRATT, M.Sc., Research Fellow at the Owens College, were elected ordinary members of the Society.

Ordinary Meeting, November 12th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. W. B. FARADAY, LL.B., showed a stone adze, one of several similar implements which have been found from time to time near Leek. He suggested a comparison with the eolithic stone implements recently shown to the Society by Mr. R. D. Darbishire.

Dr. C. H. LEES described the Hampson air-liquefying apparatus presented to the Physical Laboratories of the Owens College by Sir Henry E. Roscoe. After explaining the principle on which the action of the apparatus depends, and describing the experiments of Joule and Thomson, which led to the discovery of that principle, Dr. Lees gave a *résumé* of our present knowledge of the properties of liquid air and of other bodies when cooled down to the temperature of liquid air.

Dr. LEES illustrated his remarks by experiments, which included the following:—Liquid air boiling in an ordinary test-tube; liquid air quiescent in a Dewar vacuum vessel; liquid air boiling in a cup of ice; liquid air floating on water; ignition of glowing splinter of wood when immersed in liquid air; india-rubber, fruit, and raw meat shown to become rigid and brittle at the temperature of liquid air; frozen mercury joint between two bars of metal, under tension; bar of mercury forged into a hook from which weights were suspended; absolute alcohol frozen in liquid air.

A discussion ensued as to the industrial applications of liquid air, in which Dr. F. H. Bowman, Mr. W. Thomson, and others took part.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, November 18th, 1901.

CHARLES BAILEY, F.L.S., President of the Section, in the Chair.

Mr. J. FENWICK ALLEN exhibited, on behalf of his son, some tropical Lepidoptera.

Mr. P. CAMERON exhibited several fine Hymenoptera, collected by Mr. J. Stanley Gardiner in the Laccadive and Maldive Islands. Among them were many species new to science, and recently described by Mr. Cameron. The following letter, in conection therewith, was read :—

"The collection of Hymenoptera which I send for exhibition were collected by Mr. Stanley Gardinei, of Cambridge University, who visited the islands under the auspices of the British Association and the Royal Society Government Grant Committee. The islands are interesting from their position in the Indian Ocean, as being "stepping stones" between India and the East Coast of Africa, and they may explain how the undoubted Indian element of the East African fauna has got there. The islands are small, are very flat, few of them being 15 feet above the sea level, and are chiefly used for the cultivation of the coco-nut palm, the annual value of which is said to amount to about £13,000. They are situated near the equator. Until the completion of Mr. Gardiner's book it is not possible to come to any very definite conclusion regarding the fauna as a whole, especially taking into consideration the fact that the East African fauna as a whole is not very well known."

Mr. J. C. MELVILL showed the original MS. of Buxton's *Botanical Guide*, published in 1849. The late Mr. E. W. Binney, F.R.S., had long befriended the author, Mr. Richard Buxton, and eventually became the possessor of this interesting relic. He in turn bequeathed it to the late Mr. Thomas Rogers, and from him it came into the possession of the exhibitor. Mr. Melvill also read a short account of Buxton's life.

General Meeting, November 26th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Dr. FRANCIS V. DARBISHIRE, Assistant Lecturer and Demonstrator in Chemistry at the Owens College; Mr. REGINALD C. CHEVALIER, M.A., Mathematical Master at the Manchester Grammar School; Mr. WILLIAM WILSON, M.A., Principal of the Royal Technical Institute, Salford; Mr. STANDEN PAINE, Chemical Manufacturer, Bowdon; and Mr. FREDERICK JACKSON, Scientific Apparatus Maker, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, November 26th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. Among the recent donations were the following :—"*Catalogue of Greek Coins in the Hunterian Collection, University of Glasgow,*" by George Macdonald, Vol. 2.) 4to., Glasgow, 1901), presented by the Trustees of the Hunterian Coin Catalogue Fund; and "*Erinnerungen der Robert Wilhelm Bunsen und seine wissenschaftlichen Leistungen,*" by Heinrich Debus (8vo., Cassel, 1901), presented by the author.

Mr. C. E. STROMEYER said that, as photographs of the nebula surrounding Nova Persei are now being taken, the necessary elements will soon be available for calculating its parallax, which is equal to the ratio of the radial velocity as measured by the spectroscope, and the same velocity as measured photographi-

cally. The mass of the star can also then be determined. The matter is, however, complicated by the fact that, whereas early photographs of the surrounding nebula are not available, spectroscopic measurements are now impossible.

Professor H. B. DIXON mentioned that Mr. H. Brereton Baker had succeeded in making a mixture of hydrogen and oxygen so pure that it would not explode when the vessel containing it was raised to a red heat or when a silver wire was melted in it. In one case some water was gradually formed, so that the explosion of the gases would seem to depend on the presence of some impurity other than steam itself.

Professor F. E. WEISS exhibited two dwarf Japanese trees which have been purchased for the Manchester Museum. They were *Pinus parvifolia* and *Thuja obtusa* (the Japanese cypress), both natives of Northern Japan, where they are found at very great altitudes and are naturally of small growth. The trees exhibited, which were 30 and 40 years old respectively, were only six to nine inches in height, these dwarf forms being obtained by a system of starving and pruning back the plants, and by contortions of the stem and branches which retard the nutritive processes.

Mr. J. E. PETAVEL read a paper entitled "**On the measurement of high explosive pressures.**"

The paper was illustrated by lantern slides, and was followed by a discussion, in which Professor Dixon, Dr. F. H. Bowman and others took part.

General Meeting, December 10th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. HERBERT MASSEY, Merchant, Burnage; Mr. HOWARD SPENCE, Chemical Manufacturer, Sale; Mr. F. BADEN BENGER, F.C.S., F.I.C., Manufacturing Chemist, Knutsford; Dr. HERBERT RAMSDEN, Ch.B., Dobcross, near Oldham; Mr. HAROLD ADAMSON, Engineer, Hyde; and Miss ISA L. HILES, M.Sc., Science Mistress at the Manchester High School for Girls, were elected ordinary members of the Society.

Ordinary Meeting, December 10th, 1901.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The recent accessions included Newstead's "*Monograph of the Coccidæ of the British Isles*," Vol. I. (8vo., London, 1901), purchased from the Ray Society.

Mr. J. COSMO MELVILL exhibited the original MS. of the *Botanical Guide to the Flowering Plants . . . found indigenous within sixteen miles of Manchester* (1849), by Richard Buxton, of which a second edition was published ten years later. He explained that this interesting relic had first been bequeathed by the author (who died in 1865) to the late Mr. E. W. Binney, F.R.S., and that he, in turn, left it to the late Mr. Thomas Rogers, an Associate of the Microscopical and Natural History Section of this Society. On Mr. Rogers' sudden death on May 30th, 1901, his botanical collections (extremely rich in Cryptogamia) came into Mr. Melvill's possession, this MS. being acquired at the same time, and Mr. Melvill had asked the Council to accept it as being worthy of preservation in the Society's archives.

The following paper was read :—

"The Topographical Distribution of Mechanical Inventions in the County of Lancaster, and their Influence on some British and Foreign Industries."

By Sir WILLIAM H. BAILEY.

[ABSTRACT.]

There having been some controversy recently respecting the topographical distribution of men of genius, it was considered that it might be of interest to collect the names of Lancashire men of mechanical genius who have assisted to found our industries. To enable their influence to be measured and appreciated, a short account is given of our industrial position before their advent.

In the first half of the seventeenth century Torricello invented the barometer for indicating the pressure of the atmosphere ; we had the thermometer, the pendulum, the telescope and the microscope from Galileo ; and in this country, only a few years afterwards, we received the experimental engines from the Marquis of Worcester in 1663, and Savory's engine in 1698. Newcomen invented his simple vacuum or atmospheric engine in 1712, which we must not forget did useful work in this country for a hundred years before James Watt's double-acting engine, with the conical pendulum or governor balls for controlling it, became popular.

In 1700 we were not superior, nor even equal, to the manufacturers on the Continent. We had a small trade in iron in London, Bristol, Sheffield, Birmingham, and Manchester, but we bought all our bar iron from the Continent. All cooking pots came from Holland, and we imported all our cast-iron hollow-ware. We made a few anchors ourselves, we had a small trade in wrought-iron pans and shovels in Wigan and in the Black Country, and our chain smiths were very ingenious ; but the iron bars came from abroad. Round and square iron was hammered to shape laboriously on the anvil, or by swages and tilt hammers, but it was of bad quality.

In spinning and weaving, dyeing and bleaching, we were inferior to the people of the Low Countries, and about this time

the Dutch loom was introduced into Lancashire. Paper making had been introduced by foreigners in the reign of Henry VIII., and a few mills existed in the time of Elizabeth, but the best paper for printing books came from the Continent. From Holland came improved windmills and the waterwheel, whilst Dutch engineers were engaged in erecting pumps and providing water supplies, and the Norfolk Broads and the Bedford Level were also finished under Dutch management in the reign of Charles II. The goldsmiths of Bristol, York, and London did some good work, but in metal-work and in textile fabrics we were much inferior to foreign countries. both in design and manufacture.

Soon after the commencement of the eighteenth century, Manchester and Liverpool increased rapidly in importance, and Manchester in 1720 obtained a Bill for making the river Irwell navigable to the Mersey and to the sea. The increased facilities thus afforded gave a great impetus to the industrial prosperity of Lancashire.

The greater demand for textile goods for export caused those engaged in the trade to desire means of increasing the production, and the fly shuttle, an invention that doubled or trebled the output of the weaver, came from Kay, of Bury, in 1733. Many other machines were invented by the unfortunate Kay, who was much ill-used by those whom he had benefited, and was obliged to leave Bury to save his life. He died in poverty and obscurity in France, the place of his burial being unknown. This new system of weaving quickly exhausted all the productions of the spinsters, for the new looms could use more weft and warp in a day than the spinsters could produce in a week. Inventors were thus naturally led to consider how to increase the production of the spinning wheel, the result being the invention of the spinning jenny. A careful consideration of the claims of James Hargreaves, of Blackburn, and Thomas Hayes, of Leigh, tends to prove that they invented the spinning jenny simultaneously and independently. Between 1766 and 1769 Hayes produced one with six spindles, and, about the same time, Hargreaves made one with twelve spindles.

W. T.

RICHARD ROBERTS.

The next important invention was that of Samuel Crompton, of Bolton. It was still found impossible to meet the demand created by the new loom, and, in the year 1775, Crompton invented the spinning mule. At this time, most of our fine yarns were imported from India, but by the year 1805 we began to send fine yarns back to that country. Crompton was in great fear at one time because of the enmity of workmen, and in 1811 the Government made him a grant of £5,000. He died in 1827, and in 1862 a fine bronze monument was erected in Bolton to commemorate him.

At the commencement of the nineteenth century, many men were applying themselves to the driving of Kay's loom and Crompton's mule by steam power, but it was reserved to two Stockport manufacturers, Radcliffe and Horrocks, to invent

the first practical steam loom, in 1805. This produced a famine in yarn which continued until 1834, when the self-acting mule was invented by Richard Roberts. It is now used extensively all over the world, and is one of the inventions that have placed Lancashire manufacturers in the front rank. Roberts was one of the greatest mechanical inventors of the nineteenth century. Although he never went to school, he was an accomplished mathematician and draughtsman, and would never permit experimental work to proceed until high-class detailed drawings were prepared. Amongst his many other inventions may be mentioned the slide lathe, the metal planing machine, the pentagraph automatic drilling machine, and the jacquard punching machine for punching plates for boilers and for bridge building. Although the men of Manchester had agreed to allow him £1,000 a year if he would come to live in Manchester, he died in poor circumstances in London, and was buried in Kensal Green Cemetery. It is to be hoped that some day we may have a monument to his memory in Manchester.

John Wilkinson was born at Clifton, Cumberland, but removed to Furness as a boy, and at one time had an iron-works at Warrington. He invented the first iron boat, at Cartmel, in 1786. He also invented the steam blower, and made the first boring machine for engine cylinders. In course of time he became prosperous, and is a somewhat isolated instance of a wealthy inventor.

William Sturgeon, the inventor of the electric magnet, was born near Lancaster. He enlisted in the Militia, and then in the Royal Artillery. He began to study thunderstorms, lightning, and electricity, and in 1825 presented to the Society of Arts his first soft iron electro-magnet, for which he was awarded a premium of 30 guineas and a silver medal. He started the *Annals of Electricity*, to which Joule was a contributor. He also lectured at the Mechanics' Institute and the Salford Lyceum. His life was one perpetual struggle with adversity, and, in 1850, the first Bishop of Manchester (Dr. Prince Lee), Mr. E. W. Binney, and the Literary and Philosophical Society of Manchester petitioned the Government on his behalf, obtaining for him a grant of £200 and an annuity of £50, which, however

JAMES PRESCOTT JOULE.
(From a photograph by Lady Roscoe.)

he only enjoyed for fifteen months. He died in 1851, aged 67, and was buried in Prestwich Churchyard.

Great improvement in the quality of manufactured iron was effected by the invention of the puddling furnace by Henry Cort, of Lancaster, in 1784. Its object was to remove the impurities in English iron, and its success was immediate and remarkable. Cort also made rolling mills with grooved rollers, and his inventions gave a great impetus to the production of iron, which rose in two or three years from 90,000 tons to 5,000,000 tons per annum. He died poor, chiefly through unfortunate partnerships.

James Nasmyth was a native of Edinburgh, and came to

Manchester when a young man. The steam hammer invented by him was designed at Patricroft to meet the increasing demand for larger forgings. The distinguishing feature of Nasmyth's invention is the valve, which enables the hammer to be brought down on the hot metal with great precision.

James Prescott Joule was born in Salford, in 1818. In addition to discovering the mechanical equivalent of heat, he was the first to invent electric welding, and his investigations in electricity generally have been of considerable scientific value. His name is placed among mechanical inventors, since he invented the mechanism which proved the accuracy of his theories.

The patent lever watch was invented not in France, as has been asserted, but by Litherland, of Warrington, in 1791. He also invented a keyless watch.

To William Hughes, a Manchester man, and the first Master and Governor of Henshaw's Blind Asylum, Manchester, is due the invention of the typewriter, the steel types of which caused the letters to be embossed on the paper, so as to be easily read when touched by the sensitive fingers of the blind. Since the death of Mr Hughes, the ink roller has been added, and the modern typewriter is the result.

The name of John Ramsbottom is well known in connection with railway engineering. He invented the double safety valve, the method of feeding moving locomotive tenders with water, made many improvements in looms, and designed the condenser lubricator for engines. His most important invention was the "weft-fork" for steam looms, which greatly increased the productive power of the weaver.

British commercial supremacy owes mnch to these Lancashire inventors, whose genius has changed the entire face of this country, and increased our national prosperity. It is the more to be deplored, therefore, that these men were generally subjected to ill-treatment at the hands of the communities they benefited, and that, with one or two exceptions, they died in poor circumstances. One may, perhaps, be excused for cherishing the hope that space may be afforded in the suggested New Art Gallery of Manchester for portraits of the men of genius of Lancashire.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, December 16th, 1901.

CHARLES BAILEY, F.L.S., President of the Section, in the Chair.

Mr. H. HYDE exhibited specimens of *Salvinia natans* and *Azolla filicula*, growing, the former showing fructification.

The PRESIDENT noted the discovery at Hatchmere, Delamere Forest, of the rare sedge *Cladium jamaicense*, Crantz, perhaps better known as *C. Mariscus*, R. Br.

Mr. J. C. MELVILL, M.A., read a paper on the genus *Chrysanthemum*, L., with special reference to the origins of the cultivated species *C. indicum*, L., and *C. sinense*, Sabine, wild examples of which, from his herbarium, were exhibited. These were collected mostly by Mr. Hastings C. Dent, F.L.S., in 1886, from the vicinity of the Ming Tombs, Pekin, China, the ray florets being pink, with yellow disk. The *C. indicum*, not found wild anywhere in India, is native in China and Japan, and is the origin of the short-petalled varieties and pom-poms.

General Meeting, January 7th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. MICHAEL LONGRIDGE, M.A., M.Inst.C.E., Chief Engineer to the Engine, Boiler, and Employers' Liability Insurance Co., Ltd., Manchester; Mr. ERNEST F. LANGE, Manager of the Steel Department of Messrs. Beyer, Peacock and Co., Ltd. Gorton; and Dr. DAVID B. HEWITT, Chemical Manufacturer, Northwich, were elected ordinary members of the Society.

Ordinary Meeting, January 7th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. Amongst the recent donations were the following:—"*Prodromus Florae Batavae,*" Editio altera, Vol. 1, pars 1 (8vo., Nijmegen, 1901), published by the Nederlandsche Botanische Vereeniging, and presented through the Provinciaal Utrechtsch Genootschap van Kunsten en Wetenschappen; Macoun's "*Catalogue of Canadian Birds,*" Part I., (8vo., Ottawa, 1900), presented by the Geological Survey of Canada; "*Le Opere di Galileo Galilei,*" Vol. 11 (4to., Firenze, 1901), presented by the Ministero della Istruzione Pubblica, Italy; and Gegenbaur's "*Vergleichende Anatomie der Wirbelthiere,*" Bd. 2 (8vo., Leipzig, 1901), presented by the author.

The PRESIDENT referred to the loss sustained by the Society through the death of Dr. Henry Browne, one of its oldest members, having been elected in January, 1846.

The PRESIDENT also announced that the Society was indebted to Dr. Edward Schunck, F.R.S., for a mural tablet, placed in the Secretaries' room, bearing the following inscription:—"This room was the laboratory of John Dalton; here his great discoveries were made, and here he conceived and worked out his atomic theory."

Mr. J. COSMO MELVILL, M.A., F.L.S., made the following communication :—

Notes upon Chrysanthemum sinense, Sabine, and C. indicum, L.

The first mention of the word *Chrysanthemum*, as applied to a plant, is to be found in Dioscorides (iv. 88), being there used in connection with Χαλκάνθεμον, probably another species of the same order (Compositæ), with brazen or coppery coloured flowers, as opposed to the more pure golden hue of the Χρυσάνθεμον.

We next find Pliny, (21, 25, 26) applying it, in its Latinised form, to the same group of plants, and it was eventually adopted, with *Leucanthemum*, by Tournefort, who divided the species into two series, (*a*)with yellow, and (*b*)white rayed florets. *Vide* Linnæus '*Syst. Nat.*' i. (1735); Schub. 1307; Jussieu, 183; Vent. 2,546; Gærtn. 990; Murr. p. 773; Thunb. Jap., p. 320.

Chrysanthemum, as a genus of Compositæ, section Anthemideæ, is divided by Bentham and Hooker (*Gen. Plant.*, ii., pp. 425, 426) into five more or less natural sections. The section to which *C. indicum* and *C. sinense* belong is that of *C. Leucanthemum* L. and *C. Parthenium* L. Maximowicz retains the name *Pyrethrum* as a separate genus for the Japanese and Chinese frutescent species.

The *Chrysanthema* (inclusive of *Pyrethrum*) which occur within the boundaries of the Chinese Empire are, according to Forbes and Hemsley (*Journ. Linn. Soc.* (*Botany*), xxiii. (1888), pp. 437–439), but six in number. Placed in alphabetical order they run thus:—*C. coronarium* L., *C. indicum* L., *C. oreastrum* Hance, *C. segetum* L., *C. sibiricum* Fisch., *C. sinense* Sabine, with the var. ? *vestitum* Hemsl.

Of these the first is the well-known yellow-flowered plant, with finely pinnatisect leaves, native of the South of Europe, often cultivated in gardens, not only in England and Europe, but in

the East, mentioned as an alien in Hooker's *Flora Brit. India*, vol. iv., p. 314. It is the *Pinardia coronaria* Less. *C. oreastrum* Hance (*Journ. Bot.*, 1878, p. 108), a rare fleshy-leaved plant, with trisect linear segments, solitary terminal flowers, scales of the involucre scarious, linear oblong, without white, tomentose, the wide membranaceous margin ferrugineous and very glabrous. From Mount Siao, Wu-tai-shan, N. China, coll. Hancock, 1876.

C. segetum L. is the well-known glaucous corn marigold, a common denizen in England, mainly in cultivated ground, and abundant throughout Europe. *C. sibiricum* Fisch., better known as *C. arcticum* L., is a native of N. Siberia, E. Lapland, extending to China, and bears a superficial resemblance to the British marguerite (*C. Leucanthemum* L.).

The two remaining species, *C. indicum* L. and *C. sinense* Sabine, have been by some authors confused, and often amalgamated as one species; and it is to them that in this paper I would ask attention. The chief differences appear to be:—

	C. indicum.	*C. sinense.*
Leaves.	Flaccid, stalked, somewhat pinnatifid, finely dentate.	More coriaceous, often glaucous beneath, stalked, sinuato-pinnatifid, dentate.
Ray.	Mostly yellow, short.	Long, pink or white.

Forbes and Hemsley (*l.c.*, p. 438) remark:—"A. P. De Candolle and other contemporaneous botanists distinguished *C. indicum* from *C. sinense*, and Maximowicz and Franchet likewise recognize two species. We have followed them, though we do not find it easy to determine some of the forms. *C. indicum* is characterized by having thinner, green, not glaucous, leaves, more completely scarious involucral bracts and short yellow ray-flowers." It is noted as occurring in the Provinces of Chihli,

Shingking, Kiangsu, Chekiang, Kiangsi, Fokien, Hupeh, and the island of Hong Kong.

C. sinense Sabine (*Trans. Linn. Soc.*, xiii., p. 561, xiv., p. 145 sqq.) is very much the handsomer species in a wild state, and doubtless is the ancestor and origin of all the long-petalled cultivated forms, seen in such variety of form and colour, varying from white to pale cinnamon, brown, maroon, red, purple, rose, and bright yellow.

Sir J. E. Smith (Rees' *Cyclop.*, viii., CHRYSANTHEMUM) remarks: that "*C. indicum*, [with which he merges *C. sinense*] is a native of China, where, and in other parts of the East, it has been long cultivated, and highly esteemed for its beauty. A great number of varieties have, in consequence, been produced, single, semi-double, and double, sometimes the size of the palm of the human hand. Though this magnificent plant has so long been cultivated in the East, it does not appear to have found its way to Europe till 1795, when it flowered for the first time in Britain, in the collection of Mr. Colville, nurseryman, at Chelsea. The Chinese employ it to decorate their houses and tables on festive occasions, and are said to prefer those pieces of porcelain on which it is painted."

In *Curtis's Botanical Magazine*, Vol. ix. (1796), p. 327, with a plate taken from the first specimen that, as just mentioned, flowered in Mr Colville's nursery, is given a full account of the history of the plant, here also called *C. indicum*, with *Matricaria sinensis* Rumph. as a synonym. Rumphius (*Herb. Amboin.*, p. 259, t. 91) refers to these two species as varieties, the white and yellow flowered, probably corresponding with *C. indicum*, and the red-coloured from Amboyna, where it was only known cultivated. It is mentioned by Thunberg first, in his *Flora Japonica*, as a native of Japan, and was long before his time cultivated throughout the length and breadth of that country for the beauty of its flowers. We would also refer to Kæmpfer (*Amœn. Exotic.*, p. 875), where the plant is called by its vernacular name of Kikku or Kikf. It is noted by Forbes and Hemsley, as

occurring in the following Chinese Provinces:—Chihli, near Pekin, Hupeh, Hong Kong, Luchu Archipelago.

Among the specimens exhibited from my Herbarium the most characteristic are:—

(*a*) *C. indicum* L., near Bumgalow, Hong Kong, 1893; coll. C. Ford.

(*b*) —— varietas. Tokyo, Japan.

(*c*) *C. sinense* Sab., Ming Tombs, Pekin; coll. Hastings C. Dent, October, 1886.

(*d*) —— var. *japonica* Max.
Kodgube, Japonica, 1892, ex herb. A. Owston.

In the variety the upper leaves are less divided, and cuneate. Petals in both forms long, pink or pale purple, disk yellow.

It may be added that Sabine's remarks (*Trans. Linn. Soc.*, *l.c.*) as to the distinctness of these two species are well worth perusal; none will now doubt the correctness of the conclusions there drawn so admirably.

Mr. R. S. HUTTON read a paper on "**The Fusion of Quartz by means of the Electric Arc.**"

Dr. GEORGE WILSON read a paper entitled, "**On the Failure of certain Cast-steel Dies used in the Manufacture of Drawn Tubes.**"

Mr. C. E. STROMEYER read a paper on "**Chemical Gas Washing Apparatus,**" and exhibited some chemical gas washers which he had designed for dealing with relatively large volumes of gas.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, January 13th, 1902.

CHARLES BAILEY, F.L.S., President of the Section, in the Chair.

The following paper was read :—

Note on two probably introduced Parasitic Hymenoptera in New Zealand.

By P. CAMERON.

Among the Hymenoptera sent me by Mr. G. V. Hudson, F.E.S , from the Wellington district, was a *Bassus*, which had a familiar look. On investigation I came to the conclusion that, although it did not quite agree with any of my European specimens, it was identical with the Palæarctic *Bassus lætatorius*, Fabricius. The inquiry into the name of this Ichneumon has enabled me to clear up a matter which has puzzled me for some time.

In the *Trans. Ent. Soc.*, 1878, p. 3, the late Mr. Frederick Smith, of the British Museum, described two species of *Scolobates*, namely, *S. varipes* and *S. intrudens*, as being from New Zealand. There has always appeared to me to be some error here. In the first place Mr. Smith refers his *Scolobates* to the Tryphonides, whereas their proper position is among the Ophionides ; and, in the next place, I have never seen an Ichneumon belonging to the genus *Scolobates* from New Zealand. The similarity of the description of *Scolobates varipes* to *Bassus lætatorius* led me to suspect that it might have been founded on that species. I therefore forwarded a European example of the latter to Mr. W. F. Kirby, and asked him to be good enough to compare it with *S. varipes*. He did so, and found the two to be identical,

so that *Scolobates varipes* Sm. sinks as a synonym of *Bassus lætatorius*. *Scolobates intrudens* Sm. remains yet to be cleared up. It is evident enough that it is not a *Scolobates* and is probably a *Lissonota*, or it may be a *Meteorus* (Braconidæ). In any case the genus *Scolobates* may safely be deleted from the New Zealand fauna.

As regards *Bassus lætatorius*, it is now found in most parts of the world, and its geographical range appears to be spreading. It is now found in Australia, the Chatham Islands, Hawaii, North and South America, &c. It can hardly be looked upon as a beneficial insect, inasmuch as it is a parasite on those Syrphidæ, which are so beneficial in destroying, during their larval life, the destructive plant lice (Aphides). The occurrence of *Bassus lætatorius* in New Zealand is long prior (1874) to its being found anywhere else outside Europe, *e.g.*, in Hawaii.

I received this spring, from Mr. F. v. Hilgendorf, lecturer on science, Christchurch, New Zealand, a species of Braconidæ, which he had reared from a mined leaf of the European sow-thistle (*Sonchus oleraceus*). The species is a *Dacnusa*, a genus which appears to confine itself mainly to preying on the leaf-mining Diptera—*Phytomyza*, *Agromyza*. The *Dacnusa* I have not been able to identify to my satisfaction, owing to the specimens being mounted in balsam, but I have no doubt that it is an introduced species, as is also the case, probably, with the Dipterous miner on which it preys. The food-plant is probably also an introduction.* It would be interesting to rear the maker of the mines, so that its identity could be established.

There is one group whose position as a member of the New Zealand fauna appears to me to require verification. I mean the family Thynnidæ. It is included on the authority of de Saussure, who describes, in "Hymenoptera der Novara Reise," p. 112, *Rhagigaster novaræ* from New Zealand. No species of Thynnidæ has been recorded or found by anyone else in New Zealand, and I have come to the conclusion that *R. novaræ* is

* This plant, according to Bentham and Hooker, may be truly indigenous in New Zealand. It was found there by Banks and Solander.

really an Australian species. The matter is of importance, because the Thynnidæ are a typical Australian family, and the presence of a member of it in New Zealand would show some affinity between the two localities. On the other hand, if *Rhagigaster* has been included in error it lessens the connection, and would strengthen the opinion I have formed of the distinctness of the New Zealand fauna from that of Australia. The matter is well worthy of the attention of New Zealand entomologists. The females of the Thynnidæ are apterous, the males only being winged.

There are one or two other species recorded in the "Novara Reise" whose position as members of the New Zealand fauna appears to me to be doubtful. *Prosopis vicina* Sichel, recorded from Auckland and Tasmania, has not been found by anyone recently in New Zealand; and, as it belongs to a well-marked Australian section of the genus, I consider it to be an accidental introduction or an error in labelling on the part of the "Novara" naturalists.

The large Ichneumon, *Lissopimpla semipunctata* Kirby, is clearly an Australian introduction. A recent introduction also is the European ant, *Prenolepis longicornis* Fab.

General Meeting, January 21st, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. CHARLES S. ALLOTT, M.Inst.C.E., Engineer, Manchester, and Mr. T. THORNHILL SHANN, Merchant, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, January 21st, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The recent accessions to the Society's Library included the following:—Michael's "*British Tyroglyphidæ*," Vol. I. (8vo., London, 1901), purchased from the Ray Society; W. T. Black's "*The Fish River Bush, South Africa, and its Wild Animals*," (8vo., Edinburgh, 1901), presented by the author: and the "*Memorial Volume*" of the Wisconsin State Historical Society (fol., Madison, 1901), presented by the Society.

Mr. W. E. HOYLE made some remarks on a case of failure of concrete flooring strengthened by steel bands.

Professor F. E. WEISS read a paper entitled "**On Xenophyton radiculosum (Hick), and on a Stigmarian Rootlet, probably related to Lepidophloios fuliginosus (Williamson).**"

The paper was illustrated by a series of lantern slides showing sections of the specimens.

General Meeting, February 4th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. N. KOLP, Victoria Park, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, February 4th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT referred to the loss sustained by the Society in the death of Professor Cato M. Guldberg, of Christiania, elected an honorary member in April, 1894.

The PRESIDENT nominated Mr. Thomas Thorp and Dr. George Wilson to be Auditors of the Society's accounts for the session 1901-1902.

The PRESIDENT also announced that Dr. Henry Wilde, F.R.S., had consented to deliver the Wilde Lecture, entitled "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion," on February 25th, 1902.

Mr. FRANCIS NICHOLSON drew attention to a paragraph in Mr. Elijah Helm's "Chapters in the History of the Manchester Chamber of Commerce," wherein it is stated that as early as the first half of the 17th century cotton was brought from Cyprus and Smyrna to London and thence to Lancashire, where it was spun by hand on the single spindle frame. Mr. Nicholson pointed out that most of the cotton used in Lancashire at that time probably came from the West Indies, and, as confirming this, he read a letter written from London by his great grandfather, Robert Nicholson, to his brother James in Liverpool, in 1749,

where he quotes: "Jamaica cotton is sold at 16d. per lb., some of the very choicest $16\frac{1}{4}$d. per lb., Leeward Islands 14d. per lb."

Dr. F. H. BOWMAN stated that, in conjunction with his son, he had succeeded in constructing an apparatus for obtaining motive power direct from the combustion of coal at a very high temperature, a gas engine giving 10 indicated horse power being driven with a generator occupying a remarkably small space.

Mr. J. C. MELVILL communicated a paper by Mr. Peter Cameron, entitled "**Note on two probably introduced Parasitic Hymenoptera in New Zealand.**"

Mr. W. E. HOYLE exhibited two carved wooden bowls from British Columbia, and referred to the skill shown by the Indians, who have acquired great technical power, realistic figures in the round being well within their capacity to execute. Interesting examples are found in a dancing bat formed like a seal's head, in a float shaped like a swimming puffin, and in a rattle which represents a swimming goose, the colour and form of the latter being singularly true to nature.

When, however, the problem is to apply an animal form to the adornment of a particularly shaped decorative field, the conditions are altered, and are the more complex because the conventions of the country require that all the special characteristics of the animal be given; for instance, in a totem pole representing the beaver, the position of the ears indicates that an animal and not a human form is intended, the two large incisor teeth indicate a rodent, and various other signs make it clear that the animal depicted is a beaver. Similar examples of the treatment of animal forms are found in dancing masks, fish hooks, etc.

When the artist goes to work to draw the whole of an animal in a flat field of definite form, we have a series of remarkable phenomena, every characteristic of the animal being reproduced in portions, fitted in wherever there is room. For instance, in an animal represented on a box, the whole box stands for the animal, the front view being at one end, the back at the other,

and one side view at each side of the box. In a round ring, such as a bracelet, the treatment is somewhat different: the whole animal, from snout to tail, is carried round in each direction, the tail being situated at the side opposite to the head.

The importance of symbols must not be neglected. In a hat representing a beaver, we note the teeth and cross-hatched tail. Had these been omitted, an almost precisely similar design would have stood for a frog.

Of the two carved bowls exhibited, one is in the form of a seal, in which the head, with its well-marked jaw, nostrils and eyes, forms one of the handles, the other being composed of the tail, with the two hind flippers, one on either side of it. The other bowl is of rectangular shape, and probably represents a beaver, although this is not quite certain, on account of the absence of an indication of scales on the tail. Both bowls have evidently been used for food, as is shown by the grease-saturated condition of the wood.

A series of lantern slides, illustrating the foregoing remarks, was also shown.

Professor S. J. HICKSON exhibited and remarked upon some interesting specimens of Alcyonaria, collected during the last few years in Malayan waters and the Indian Ocean.

Mr. J. E. KING read the first part of a paper on "**Folklore of the North American Indians, from the Jesuit Relations (1611 to 1637).**"

General Meeting, February 18th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. WILLIAM E. MOSS, B.A., Cotton Broker, Liverpool, was elected an ordinary member of the Society.

Ordinary Meeting, February 18th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. Attention was called to the following donations to the Society's Library:—"*A Guide to the Shell and Starfish Galleries . . . British Museum (Natural History)*" (8vo., London, 1901), and "*Catalogue of the Mesozoic Plants in the Department of Geology, British Museum (Natural History). The Jurassic Flora. I. The Yorkshire Coast,*" by A. C. Seward (8vo., London, 1900), presented by the Trustees; "*The Letters of Faraday and Schœnbein, 1836-1862,*" edited by G. W. A. Kahlbaum and F. V. Darbishire (8vo., Bâle and London, 1899), and "*The Letters of J. J. Berzelius and C. F. Schönbein, 1836-1847,*" edited by G. W. A. Kahlbaum (8vo., London, 1900), presented by Dr. Francis V. Darbishire; and H. Geitel's "*Ueber die Anwendung der Lehre von den Gasionen auf die Erschienungen der atmosphärischen Elektricität*" (8vo., Braunschweig, 1901), presented by the author.

Mr. FRANCIS NICHOLSON exhibited, and presented to the Society, two books entitled "*Lectures on Electricity*" (1842) and "*A Course of Twelve Elementary Lectures on Galvanism*" (1843), by William Sturgeon, a former member of the Society.

Mr. THOMAS THORP mentioned the occurrence of two explosions of silvering solution, similar to those which he had referred to in 1900, and emphasised the danger arising from keeping this liquid after it has once been prepared.

Mr. R. L. TAYLOR read a paper "**On a Modification of Rose's Method of separating Cobalt and Nickel.**"

Mr. D. L. CHAPMAN described some experiments which have been carried out, in conjunction with Mr. F. A. Lidbury, principally for the purpose of discovering whether Faraday's law may be considered as applying to gases. The electric discharge was passed through water vapour, and the separation of oxygen and hydrogen which took place was found to be from two to three times as great as that which occurred in a voltameter placed in the same circuit. The results are, therefore, inconsistent with the view that the phenomenon is essentially electrolytic.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, February 24th, 1902.

CHARLES BAILEY, F.L.S., President of the Section, in the Chair.

Mr. J. C. MELVILL exhibited specimens of the brake fern (*Pteris aquilina* L.), from all parts of the world, showing

(*a*) typical var. *glabra ;*

(*b*) downy-leaved var. *lanuginosa ;*

(*c*) Australian and New Zealand forms of var. *esculenta ;*

(*d*) South American and Florida forms of var. *caudata.*

Likewise a curious sport, of which the President also supplied examples from his herbarium, of a beautiful form with thin fronds from the *débris* of an excavation made for a plunge bath at Coventry, Warwickshire, in 1853, by the late Mr. Thomas Kirk, F.L.S. In Vol. I. of the New Series of the *Phytologist*, pp. 390 and 463, are letters concerning this discovery, one by Mr. Thomas Moore, pronouncing it definitely to be the common Bracken, although some doubt had been cast upon this, owing to the very different appearance it assumed.

Special Meeting, February 25th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The Wilde Lecture, "**On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion,**" was delivered by Dr. Henry Wilde, F.R.S.

General Meeting, March 4th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

Mr. G. C. MANDLEBERG, India-rubber Manufacturer, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, March 4th, 1902.

CHARLES BAILEY, F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The recent accessions to the Society's Library included the following:—W. Black's "*Narrative of Cruises in the Mediterranean in H.M.S. 'Euryalus' and 'Chanticleer' during the Greek War of Independence (1822-1826)*" (8vo., Edinburgh, 1900), presented by Dr. W. G. Black; and Miss Winifred Faraday's "*The Edda: I. The Divine Mythology of the North*" (16mo., London, 1902), presented by the author.

Dr. ARTHUR DENDY (Professor of Biology, Canterbury College, New Zealand) gave a lecture on "**The Chatham Islands; a Study in Biology.**"

The lecture was illustrated by a large series of photographic lantern slides, and several objects of ethnographical interest were also exhibited.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, March 10th, 1902.

CHARLES BAILEY, F.L.S., President of the Section, in the Chair.

Mr. J. FENWICK ALLEN, read a paper on "**The Observation (or Occurrence) of Noctiluca miliaris at Red Wharf Bay, Anglesey, in July, 1901.**"

General Meeting, March 18th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

Mr. JOHN FENWICK ALLEN, Metallurgist, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, March 18th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. FRANCIS NICHOLSON exhibited, and presented to the Society, a copy of William Sturgeon's paper "*On some Peculiarities in the Magnetism of Ferruginous Bodies*" (1845).

Mr. R. F. GWYTHER, M.A., read a paper entitled "**On the Conditions which render definite the Rate of Propagation of an Earth-Tremor.**"

Mr. J. E. KING, M.A., read the second and concluding part of his paper on the "**Folk-lore of the North American Indians, from the 'Jesuit Relations' (1611 to 1637).**"

In the discussion which followed the reading of the paper,

Miss WINIFRED FARADAY drew attention to certain parallels in Old Norse beliefs. She pointed out that in Iceland also, as was proved by a passage in *Hardar Saga*, infanticide was permitted in the case of a new-born and nameless child, but was treated as murder if the child had received a name. The simultaneous existence of inconsistent beliefs as to the state of the dead was exemplified in the Helgi poems in the *Edda*.

Microscopical and Natural History Section.]

Annual Meeting, April 14th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President of the Section, in the Chair.

The Council presented the following report of the Section for the Session 1901-1902 :—

"Your Council, in presenting a report for the past Session, has again to record a reduction in both the membership and the associateship of the Section, the present list consisting of but 14 members and 8 associates, as against 17 and 11 respectively, at the close of the preceding session.

"The cash in the bank at the credit of the Section amounted, in April, 1901, to £24. 5s. 5d., and this is reduced to £10. 18s. 0d. at the date of this report.

"Some years ago, when the membership was larger, an arrangement was entered into with the parent Society, under which, and in view of the large number of its associates, the

annual sectional contribution was increased from £2. 2s. od. to £5. 5s. od., and the amount of £10. 10s. od., being such contribution for two years (1900-1901 and 1901-1902), has been included in the payments of the current session.

"The regrettable reduction in membership, just alluded to, has been going on for many years, and must be attributed to the increasing specialisation which has been taking place in microscopical studies and biological research, each branch of science wishing to form a separate organisation to foster its individual pursuits.

"Under these unfortunate but apparently unavoidable circumstances, it would seem desirable to dissolve the Section, at the same time urging its present members and associates to make their communications to the ordinary meetings of the parent Society. A resolution will subsequently be submitted to the Annual Meeting bringing to a close the operations of the Section as a separate organisation, and authorising the Treasurer, after discharging the obligations of the Section, to pay over to the Treasurer of the Society the balance which remains at the credit of the Section at the Williams Deacon's Bank, and in his own hands.

"The Council has not come to this determination without unfeigned regret, especially as the Section, instituted in December, 1858, is but a few years distant from the celebration of its Jubilee, having been in existence nearly 44 years. Many distinguished men have been members or associates, and mostly contributed papers at its meetings. Its career has been honourable, and its record both good and useful. It is hoped however that, by its dissolution, the biological side of the parent Society will receive a favourable impetus.

"In conclusion, the Council would wish to place on record the deep sense of the loss the Section sustained early in the present session, by the sudden death of Mr. Thomas Rogers, at Patterdale, on 30th May, 1901. Most regular in his attendance at both the Council meetings and ordinary meetings, as an associate of over 28 years' standing (having been elected on

18th March, 1873), he was always to be depended upon for some object of interest to be exhibited, some current question of biological interest to be dilated upon, or some short paper to be read, thereby much increasing the interest of the monthly meetings during many sessions."

The Treasurer submitted the following account of the receipts and disbursements of the Section during the past session :—

John R. Ragdale, in Account with the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society.

Dr. SESSION 1901-1902. *Cr.*

	£	s.	d.		£	s.	d.
To Balance at Bankers and cash in hand, April, 1901	24	5	6	*By* Subscription to Parent Society, 1900-1 and 1901-2.	10	10	0
,, Subscriptions and Arrears	7	10	0	,, Books and Periodicals	4	3	0
,, Bank Interest......... ..	0	8	0	,, Tea, coffee, etc. at Meetings	2	11	$0\frac{1}{2}$
				,, Printing & Stationery	3	3	6
				,, Postages, etc.	0	17	$11\frac{1}{2}$
				,, Balance, April 11th, 1902	10	18	0
	£32	3	6		£32	3	6

Audited, April 11th, 1902,

(*Signed*) {JOHN BOYD.
JNO. FENWICK ALLEN.

The report of the Council and the Treasurer's account were then approved and passed.

On the motion of Mr. HENRY HYDE, seconded by Mr. W. E. HOYLE, it was unanimously resolved :—"That the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society be and is hereby dissolved ; and that the Treasurer, Mr. J. R. Ragdale, is hereby authorised by the Section to discharge all its obligations from the funds in

hand, and pay over the remaining balance to the Treasurer of the Manchester Literary and Philosophical Society, to be expended for natural history purposes. The Treasurer is also hereby authorised to formally convey to the same Society, in the name of the Section, the microscopes, cabinets of slides, books, photographs, papers, and all other property belonging to the Section at the date of its dissolution."

Mr. HENRY HYDE exhibited various preparations and specimens dried in the usual way and then kept in an unusually dry place; thus the colour of *Centaurea nigra* was kept intact and the stamens from catkins of *Salix Caprea* looked as if still imbued with life.

Mr. J. COSMO MELVILL exhibited *Mitra zonata* Marryat, from the Mediterranean. This, the most highly prized of all the mollusca from the above locality, is specially interesting in a two-fold way. First, being one of the two shells described (*Trans. Linn. Soc.*, Vol. xii., 1818) by Captain F. Marryat, R.N., the famous novelist; and, secondly, because it is so rarely found, though the distribution is wide.

The specimen exhibited came from Villefranche, near Nice. Of the twenty or so examples in Continental and British collections, three are in the British Museum; one, in that of the Marquis de Monterosato, is the largest and finest known, being four inches in longitude; Mr. E. R. Sykes possesses a very fine example; also M. Dautzenberg, of Paris. Of late, Mr. Pallary has been successful in dredging it from a good depth, say 400 fathoms. It has occurred at Algiers, off Oran, near Villefranche, on the Sicilian coasts, and (it is believed) in the Adriatic also.

The shell is of great specific gravity, many whorled, heavy, mouth oblong, rather narrow, columella five-plaited, smooth, covered with a thick shining epidermis, the upper part of the whorls transversely banded.

General Meeting, April 15th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

Mr. HENRY HYDE, Brooklands, was elected an ordinary member of the Society.

Ordinary Meeting, April 15th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Attention was called to the following accessions to the Society's Library:—Mourlon's "*Bibliographia Geologica*," Série B, Tome 4 (8vo., Bruxelles, 1901), purchased; Matiegka's "*Bericht über die Untersuchung der Gebeine Tycho Brahe's*" (4to., Prag, 1901), Studnicka's "*Bericht über die astrologischen Studien des...Tycho Brahe*" (4to., Prag, 1901), and "*Bericht über die Saecularfeier der Erinnerung an das vor 300 Jahren erfolgte Ableben des...Tycho Brahe*" (4to., Prag, 1902), presented by the K. Böhmische Gesellschaft der Wissenschaften; J. Willard Gibbs' "*Elementary Principles in Statical Mechanics*" (8vo., New York, 1902), presented by the author; J. J. Gleave's "*Yorkshire Caves*" (8vo., Manchester, *n.d.*), presented by the author; "*Proceedings of the International Engineering Congress, Glasgow, 1901*," 2 vols. (4to., London, 1902), and McLean's "*Local Industries of Glasgow and the West of Scotland*" (8vo., Glasgow, 1901), presented by the International Engineering Congress.

Mr. F. J. FARADAY exhibited an old copy of Chateaubriand's "Atala," partly written in the huts of the American Indians in Louisiana and Florida during the author's first visit to the New World in 1789, and containing passages showing the continued

existence amongst the Red Indians at the end of the eighteenth century of some of the religious beliefs and practices referred to in Mr. J. E. King's recent paper on the Jesuit records of 1611, noticeably with regard to the metempsychosis of the souls of infants, the exhuming of the bones of members of the family from the temporary village grave for reburial in a common national grave on the occasion of the "Feast of the Dead," or the "Feast of Souls," and the transporting of the bones of dead relatives during migration.

Professor F. E. WEISS exhibited a specimen of *Welwitschia mirabilis.* This curious plant was discovered by Dr. Welwitsch in 1860 in the South-west of Africa, where it grows in very arid regions, rooted by a very long tap root. The upper part of the plant is protected by a very thick mantle of cork. It only possesses two leaves, which last throughout the life of a plant, being constantly renewed from the base, which lies protected in a groove of the stem. *Welwitschia* was first described by Sir Joseph Hooker, who considered it as belonging to the group of Gnetaceæ allied to the Conifers.

Dr. HENRY WILDE, F.R.S., read a paper "**On the Atomic Weights and Classification of the Elementary Gases, Neon, Argon, Krypton, and Xenon.**"

A note by Mr. THOMAS KAY, entitled "**On the Hypnotic Influence produced by Persistent Motion and Sparkling Objects,**" was read by Mr. F. J. Faraday, in the author's absence.

Light is an attraction to human beings, and has a strong influence upon the brain. A great addition to the attractiveness of light is motion—thus, on the brooks, rivers, seas and oceans, where light, motion and sound most predominate, there is the greatest attraction, and one can spend a whole day beside a sparkling waterfall, or a week beside a Niagara without being bored.

Not only has a bright and shining object a peculiar attraction for human beings, but it affects also the lower animals. The trappers of migratory birds are acquainted with this fatal attraction

for at Grisnez lighthouse, between the 10th and 14th of October, 1901, 6,000 birds were caught by means of nets placed underneath its brilliant lights; and a revolving mirror is used in some countries to attract birds for the so-called sportsmen to shoot. The moth will continue to flutter around the lighted candle until it is irresistibly drawn into the flame, and fishes are attracted to their destruction at night, by means of a lighted torch held over seas or rivers; while migratory birds follow the setting sun in their flights.

It is well known that, by staring fixedly at a bright piece of metal on a dark disc, the mind becomes hypnotised, as observed Dr. James Braid of Manchester. This effect is also easily produced in any fowl by the old experiment of placing it with its beak to the ground, and drawing therefrom a chalk mark in a straight line, which is infinity to its poor brain and it becomes hypnotised.

I have an overmantel mirror, and, when seated before the fire, the reflection of the lamp obtrudes itself so persistently that I have to cover it. I find it impossible to avoid looking at it, for one's eyes irresistibly travel and unconsciously find the light, until it becomes so irksome that I turn away discontented or cover up the mirror with any convenient material.

A scientific man of my acquaintance informs me that, when he was about 15 years of age, whilst watching a pair of bevel wheels revolve which were attached to the governors of a steam engine, he felt an almost irrepressible desire to put his finger between the cog-wheels, well knowing what the result would be, and had he remained gazing at them for a sufficient length of time, the desire would have been too strong for him to resist.

Another case is that of a boy about 12 years of age, who was attracted by a hole in the roller of a beaming frame, and had an irresistible desire to place his finger in it, with the result that the finger was badly crushed.

It is well known that serious railway accidents are often caused by a pointsman pulling a wrong lever. Is it not possible that he becomes hypnotised by viewing the polished levers, and

that under these circumstances he cannot have control over his actions? If these levers were covered with a dead surface, at least one possible cause of accident would be removed. A man may look down a coal-pit quite easily without confusion to the mind, whilst he cannot so easily look down from a high cliff upon the moving sea below; this is doubtless due both to the motion and to the shining appearance of the water. Accidents also frequently occur through workpeople falling into vats of boiling liquor, which would seem to show that the vats ought to be covered or otherwise protected. If these accidents are traced to their source, I think they will frequently be found to be due to the semi-dazed or hypnotic state of the individual.

ANNUAL GENERAL MEETING, APRIL 29TH, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

Mr. FRANCIS SORELL ARNOLD, M.B., Ch.B., Manchester, Miss MARY DENDY, Withington, and Mr. ARTHUR M. HERBERT, B.A., Timperley, were elected ordinary members of the Society.

The SECRETARY announced, in accordance with Rule 22 of the Articles of Association, that the names of H. A. Henderson, and T. B. Wilson had been erased by the Council from the register in consequence of non-payment of their subscriptions.

The Annual Report of the Council and the Statement of Accounts were presented, and it was moved by Professor F. E. WEISS, seconded by Mr. W. H. TODD, and resolved:—"That the Annual Report, together with the Statement of Accounts, be adopted, and that they be printed in the Society's *Proceedings*."

The following members were elected officers of the Society and members of the Council for the ensuing year:—

President: CHARLES BAILEY, M.Sc., F.L.S.

Vice-Presidents: J. E. KING, M.A.; R. F. GWYTHER, M.A.; H. B. DIXON, M.A., F.R.S.; Sir WILLIAM H. BAILEY.

Secretaries: FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.; CHARLES H. LEES, D.Sc.

Treasurer: C. E. STROMEYER, M.Inst.C.E.

Librarian: W. E. HOYLE, M.A., M.Sc., F.R.S.E.

Other Members of Council: HORACE LAMB, M.A., LL.D., F.R.S.; J. COSMO MELVILL, M.A., F.L.S.; FRANCIS NICHOLSON, F.Z.S.; R. L. TAYLOR, F.C.S., F.I.C.; F. E. WEISS, B.Sc., F.L.S.; THOMAS THORP, F.R.A.S.

On the motion of Mr. F. J. FARADAY, seconded by Mr. R. F. GWYTHER, it was resolved :—"That this meeting expresses the thanks of the Society to Mr. J. J. ASHWORTH for the services he has rendered to the Society during his six years' tenure of office as Treasurer."

Ordinary Meeting, April 29th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The recent additions to the Society's Library included the following:—"*1851-1901. Cinquantenaire scientifique à M. Berthelot, 24 novembre 1901*" (4to, Paris, 1902), presented by the Comité du Cinquantenaire; and "*An Account of the Remains of a Roman Villa discovered at Brislington, Bristol, December, 1899,*" by W. R. Barker (8vo, Bristol, 1901), presented by the Bristol Museum Committee.

The PRESIDENT announced the death of Professor M. A. Cornu, For.Mem.R.S., of Paris, elected an honorary member of the Society in April, 1887.

Mr. FRANCIS NICHOLSON presented to the Society a framed engraved portrait of Peter Clare, F.R.A.S., who was one of the Secretaries of the Society from 1821 to 1842. On the motion of the PRESIDENT, the thanks of the members were unanimously voted to Mr. Nicholson for the gift.

Mr. FRANK F. LAIDLAW, B.A., made a communication on "**The Peoples of Malacca,**" and illustrated his remarks by a series of lantern slides.

Noticing briefly the civilised inhabitants of the peninsula, chiefly Malays, Chinese and European, special attention was directed to a number of savage nomadic communities, which inhabit the forest country of the interior for the most part. Owing to intermarriage between the various communities, as well as to the careless nomenclature employed in speaking of them, it is difficult to classify them in a satisfactory manner. In the northern half of the peninsula, however, these savages exhibit almost universally negrito characteristics, *viz.*, curly (almost woolly) hair, very dark skins and moderately long skulls (mesaticephalic); the nose also is extremely wide and very flat. These negritos occur chiefly in Kedah, Kelantan and Perak. They are known as "Semang" or "Pangan," and call themselves "Menik." Considerable intermixture of negrito blood is also found in most of the savage communities towards the south of the peninsula. Many authorities believe that the southern wild tribes are derived from an admixture of Malay and negrito blood, but the evidence tends to show that in Perak, at least, there exists a second race quite distinct from negrito or Malay—a dolichocephalic, moderately fair-skinned race with wavy hair, possibly allied to the Karens of Burmah. These people are known as "Senoi," and most of our information concerning them is due to Prof. Martin, of Zurich. Lastly, the people of Johor, Selangor and Pahang, though showing traces of negrito and perhaps of Senoi intermixture, are obviously of a mongoloid stock. Like the other two groups, their stature is small (average height of a full-grown man 4ft. 9in., of a woman 4ft. 6½in.), but the hair is straight and the skull brachycephalic. One branch of these tribes has taken to living on the sea, and has spread on to some of the islands of the Johor Archipelago. These are the "Orang Laut." Other tribes are the "Jakun" of Johore, the "Besisi" of Selangor, and the "Mantras" found

near Malacca. It is not improbable that this latter group is largely descended from Malays who refused to adopt the creed of Islam; or they may perhaps more probably be derived from the widely spread pro-Malay race, of which the Malays themselves and the Javanese, &c., are specialised offshoots.

In the discussion which followed,

Professor HICKSON, F.R.S., remarked upon the extreme interest of the photographs of the Semangs exhibited by Mr. Laidlaw, which removed all doubts as to the affinities of these people with the other isolated groups of the negrito stock. The fact that was mentioned about their use of the bow and arrow confirmed this conclusion, as it is noteworthy that so many of the negritos, such as the Andamanese, the Aetas, the Akkas, and Bushmen use bows and arrows, although surrounded by more powerful tribes by whom this weapon is not seriously used in warfare. The use of the sumpitan or blow-gun by the Semangs was probably learnt from the Malays, the only race of human beings, with the exception of the Caribs of South America, who have discovered its efficiency.

Extraordinary General Meeting, May 13th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

Mr. C. E. STROMEYER, M.INST.C.E., was elected a Vice-President of the Society, in the place of Mr. R. F. Gwyther, M.A., and Mr. JOHN BOYD was elected Treasurer of the Society in the place of Mr. C. E. Stromeyer.

The following gentlemen were elected honorary members:—Dr. JOSEPH LARMOR, SEC.R.S., Cambridge; Dr. D. H. SCOTT, F.R.S., Kew; Principal OLIVER J. LODGE, F.R.S., Birmingham; and Professor H. F. OSBORN, New York, U.S.A.

Professor SYDNEY J. CHAPMAN, M.A., Professor of Political Economy at the Owens College, and Mr. R. W. ELLISON, Moss Side, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, May 13th, 1902.

CHARLES BAILEY, M.Sc., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the tables.

Amongst the recent accessions to the Society's Library were the following :—"*Nordiske Fortidsminder,*" Hefte 4 (fol., Kjöbenhavn, 1902), presented by the Kgl. Nordiske Oldskrift-Selskab; and Whiteaves' "*Catalogue of the Marine Invertebrata of Eastern Canada*" (8vo., Ottawa, 1901), presented by the Geological Survey of Canada.

A paper on "**The Luminous Organs in Pterygioteuthis margaritifera, a Mediterranean Cephalopod,**" by Mr. W. E. HOYLE, M.A., was laid upon the table.

Professor BOYD DAWKINS, F.R.S., brought before the Society the collection of specimens discovered in 1901 in Crete by Mr. Hogarth in the course of the exploration of the Mycenean remains of that island, which is now being carried on with such wonderful results. While Dr. Arthur Evans has been working at the Palace of King Minos, Mr. Hogarth has been exploring the habitations and tombs at Zakro, in addition to carrying out the exploration begun by the former in the shrine of Zeus in the Dictaean cave. These discoveries reveal the high character of the civilisation in Crete in the Mycenean age. They prove that, ranging backwards from 1,200 B.C. to at least 2,300 B.C., there were stately palaces in Crete inhabited by rulers who adorned their dwellings with frescoes and sculpture, who possessed the art of writing in two sets of characters, and who worshipped the Dictaean Zeus. From this Mycenean civilisation the Greeks derived their art and, to a large extent, their religion.

The skulls exhibited, which Professor Boyd Dawkins has recently described in the *Annual of the British School at Athens*, 1901, belong to the oval-headed, well-developed type termed Mediterranean by Sergi, and closely allied to the Iberic type of Spain and of Britain. They bear unmistakable marks of

civilisation in the thinness of their walls and the extent to which the sutures are drawn out by the growth of the brain, as well as by the badness of their grinders and the small size of their canines. They probably were a small, dark race, and were in the Bronze stage of civilisation.

Among the remains sent for examination by Mr. Hogarth from the Dictaean cave are the skulls of a goat and a hog, portions of those of the fallow-deer, and the forehead with two horn-cores of a domestic ox, for which Professor Dawkins proposes the provisional name of *Bos creticus*, as it cannot be identified with any species on record. This last has been cut away so as to form a "bucranium" for attachment to the shrine. They were found along with remains of sacrificial vessels. In addition to the above, and in illustration of the splendour of the Mycenean civilisation in the Ægean Sea, Professor Boyd Dawkins also exhibited a series of photographs and facsimiles of two gold cups. The cups more particularly illustrate the source from which the makers of the frieze of the Parthenon derived their artistic inspiration. In them may be seen the same kind of movement and action in the hunting and taming of the wild oxen as may be traced in the action of the horses in the frieze. There is every reason to believe that the Mycenean civilisation was the parent in the Mediterranean region of that which in the western Mediterranean lived on under the name of Roman and in the eastern under the name of Greek. Its influence was felt in Europe as far north and west as the British Isles in the prehistoric Iron Age, if not in the preceding Age of Bronze.

Extraordinary General Meeting, June 3rd, 1902.

CHARLES BAILEY, M.SC., F.L.S., President, in the Chair.

The PRESIDENT was elected to the additional office of Treasurer of the Society in the place of Mr. John Boyd.

Annual Report of the Council, April, 1902.

The Society began the session with an ordinary membership of 139. During the present session 28 members have joined the Society; 5 resignations have been received, and the deaths have been 2, viz.: Mr. JOHN HAMPDEN BECKETT and Dr. HENRY BROWNE, whilst 1 member has been removed from the list for non-payment of his subscription. This leaves on the roll 159 ordinary members. The Society has also lost 5 honorary members by death, viz: Professor CATO M. GULDBERG, of Christiania, Professor H. de LACAZE-DUTHIERS, of Paris, Professor F. M. RAOULT, of Grenoble, Professor H. A. ROWLAND, of Baltimore, and Professor P. G. TAIT, of Edinburgh. Memorial notices of these gentlemen appear at the end of this report.

The Council is glad to report that, during the session, there has been a marked increase in the number of members admitted, which this year nearly equals the total of the previous four years. The attendance at the meetings has also improved, having reached an aggregate of 367, as compared with 266 last year, whilst the number of papers read before the Society has advanced from 15 last year to 18 in the present session.

The Treasurer commenced the year with a balance in favour of the Society of £119. 6s. 9d. (including £85. 1s. 8d. balance of the Wilde Endowment Fund), and reports that the total balance, exclusive of the amount still owing by the Natural History Fund, but including the Wilde and Joule Funds, at the bankers and in hand, at the close of the year is £132. 15s. 10d., in addition to £31. 19s. 2d. to the credit of the Dalton Tomb Fund.

The Librarian reports that during the session 745 volumes have been catalogued, stamped and pressmarked, 684 of these being serials, and 61 separate works. There have been written 213 catalogue cards, 126 for serials, and 87 for separate works.

The total number of volumes catalogued to date is 26,193, for which 8,594 cards have been written.

Satisfactory use is made of the library for reference purposes, but the number of volumes consulted is not recorded. During the session, 152 volumes have been borrowed from the library, as compared with 195 volumes in the previous session; it is hoped that, as the card catalogue now affords every facility for quickly finding any work required, members will make further use of the valuable collection of books possessed by the Society.

Attention has continued to be paid to the completion of sets, 11 volumes or parts having been obtained which render 4 sets complete, whilst 3 volumes have been acquired which partly complete 2 sets. These 14 volumes were presented by the respective societies publishing them. Since the commencement of the re-cataloguing of the library, a total of 802 missing volumes has been obtained, resulting in the completion of 98 sets.

Comparatively little binding has been done this session, 299 volumes having been bound in 208, whilst several volumes have undergone repair.

A record of the accessions to the library shows that, from April, 1900, to March, 1901, 682 serials and 38 separate works were received, a total of 720 volumes. The donations during the session (exclusive of the usual exchanges) amount to 30 volumes and 150 dissertations; 8 books have been purchased (in addition to the periodicals on the regular subscription list).

During the past session the Society has arranged to exchange publications with the following: Allegheny Observatory; Brooklyn Institute of Arts and Sciences; Physikalisch-Technische Reichsanstalt zu Charlottenburg; University of Missouri, Columbia; Ohio State University, Columbus; American Chemical Society, New York; Geological Survey of Natal, Pietermaritzburg; Société Scientifique et Médicale de l'Ouest, Rennes; Mathematischnaturwissenschaftlicher Verein in Württemberg, Stuttgart; Astronomical Observatory of the Smithsonian Institution, Washington.

In accordance with a resolution of the Council, there is in preparation an author-index of all the papers, communications and exhibits brought before the Society from its foundation until the year 1901, as recorded in the *Memoirs* and *Proceedings.*

The Society is indebted to the following gentlemen, for the undermentioned gifts :—

Dr. Edward Schunck, F.R.S., for a mural tablet in white marble, placed in the Secretaries' room, bearing the following inscription : "This room was the laboratory of John Dalton ; here his great discoveries were made, and here he conceived and worked out his atomic theory" ;

Mr. Thomas Thorp, F.R.A.S., for specimens of his diffraction gratings ;

Mr. W. Houghton, of Old Trafford, for a silhouette portrait of Dr. Thomas Percival, one of the founders of the Society ;

Mr. J. Cosmo Melvill, M.A., for the original MS. of Buxton's "*Botanical Guide to the Flowering Plants . . . of Manchester*" (1849) ; and

Mr. Francis Nicholson, F.Z.S., for copies of three books by William Sturgeon, a former member of the Society.

On the resignation of Professor Flux, the publication of the *Memoirs and Proceedings* was entrusted to an Editorial Committee of five members representing different departments of knowledge, and the arrangement has been found satisfactory.

The Council has to express its regret that Mr. J. J. Ashworth has intimated his intention of resigning the Treasurership at the end of the present session, and desires to record its thanks for his care of the Society's finances during the six years that he has held office.

At the celebration of the Ninth Jubilee of the University of Glasgow, in June, 1901, the Society was represented by Dr. Henry Wilde, F.R.S., and Professor Horace Lamb, LL.D., F.R.S. The address presented was as follows :—

[ADDRESS.]

Societas Litterarum Philosophiaeque Studiosorum Mancuniensis Cancellario, Curiae, Senatui Universitatis Glasguensis.

S. P. D.

Gratulamur vobis, viri amplissimi, quibus contigerit Universitati vestrae illustrissimae eo praesertim tempore praeesse cum lustrum suum nonagesimum felicissime clausum sit celebratura; simul gratias vobis agimus quod hujus tanti muneris laetitiaeque inde nascentis nos quoque participes esse voluistis, ad quod tam gratum opus suscipiendum delegimus mittimusque viros doctissimos honoratissimosque Henricum Wilde, scientiae doctorem, et Horatium Lamb, doctorem legum, ambo in socios Regiae Societatis Londinensis ascriptos. Gratulationes autem nostras scitote eo esse veriores quod memoria tenemus quanta et quam eximia fuerint merita vestrae Universitatis in causa Litterarum Scientiaeque tuenda atque sustinenda, ad quas, id quod nomen ipsum indicat, excolendas promovendasque nostra Societas est fundata: et cum gratissimis nos animis memoriam foveamus duorum praestantissimorum physicorum, qui quondam apud nos floruerunt, Joannis Dalton et Jacobi Prescott Joule, haud alienum videtur commemorare quanti apud vos jure habeantur duo physici "fama super aethera noti," Josephus Black, qui inventis suis saeculum suum illustravit, et Kelvinus ille vester, qui, cum antehac tantum contulerit ad laudem vestram et existimationem augendam, tum adhuc praeceptis et consiliis floret vigetque.

Denique vestrae Universitati eam optamus felicitatem, ut, quem locum Litterarum et Scientiae diligentissima fautrix adjutrixque diu obtinuit, eum teneat in perpetuum, et laudum suarum rerumque gestarum, si eas exsuperare nequeat, semper aemula esse videatur.

CAROLUS BAILEY, *Praefectus.*
OSBORNE REYNOLDS.
HORATIUS LAMB.
JOANNES EDUARDUS KING.
C. E STROMEYER.
} *Vice-Praefecti.*
FRANCISCUS JONES.
A. W. FLUX.
} *Librarii*

Dabamus a.d. III Id. Jun. MCMI. Mancunii.

In connection with the Berthelot celebration in Paris on November 24th, 1901, the following letter was addressed to the Secrétaire perpétuel de l'Académie des Sciences :—

[COPY.]

November, 1901.

On behalf of the Council and members of the Manchester Literary and Philosophical Society, we beg to offer our most hearty congratulations to M. Berthelot on his completion of fifty years of untiring scientific research—research extending over the whole field of pure, applied and historical chemistry.

Whether we regard the brilliant syntheses by which M. Berthelot showed that the world of organic chemistry can be built up from inorganic elements, or whether we have regard to his researches which have made a science of thermo-chemistry possible, we recognise that his work has not only been carried out with marvellous ingenuity but has always been guided by fundamental conceptions.

This Society, of which Dalton and Joule were among the chief ornaments, is proud to number M. Berthelot among its members.

We desire to offer M. Berthelot on this occasion our earnest wishes that he may long enjoy his splendid activity and his well-earned fame.

(*Signed*) FRANCIS JONES, CHARLES H. LEES, } *Hon. Secretaries.*

In December last, the Société des Sciences Naturelles et Mathématiques de Cherbourg celebrated the 50th year of its foundation, and a letter of congratulation was sent on behalf of this Society, in the following terms :

[COPY.]

The Council of the Manchester Literary and Philosophical Society desires to congratulate the Société des Sciences Naturelles et Mathématiques de Cherbourg on the occasion of its approaching Jubilee, and wishes to express the hope that the

Society, which has done so much to advance the progress of natural science in the past, may long continue to carry on its successful work.

(Signed) FRANCIS JONES, CHARLES H. LEES, } *Hon. Secretaries.*

On the occasion of the celebration of the Owens College Jubilee on March 12th and 13th, 1902, the Society was represented by the President, and the following congratulatory address was presented:—

[ADDRESS].

To the President and Council of the Owens College.

Gentlemen,

The Literary and Philosophical Society of Manchester, as an elder sister in literature, philosophy, and science, desires to offer you the heartiest felicitations upon the completion of fifty years of active corporate life, and to express the earnest hope that in the years to come the College may find an ever-widening sphere of influence, and exercise an ever-increasing power of usefulness.

During these eventful fifty years, the relations between your College and our Society have been agreeable, stimulating and intimate; your teaching staff has always found its representatives among our most zealous members and officers; and many of the students you have trained have become valued members of our Society.

We witnessed with sympathy your early struggles in the modest beginnings in Quay Street; we watched with admiration your persevering efforts to make the College worthy of the position it was destined to fill in the district, and we rejoice with you to-day in the possession of your present noble buildings and splendid educational equipment.

We pray that in the future, as in the past, it may be your happy privilege to rely with full assurance upon the affection of

your alumni, the esteem of your sister Colleges, and the munificence of the community.

Signed on behalf of the Society,

CHARLES BAILEY, *President.*
FRANCIS JONES, } *Hon. Secretaries.*
CHARLES H. LEES, }

36, George Street,
Manchester,
March, 1902.

The Council have appointed the President and Mr. Francis Jones representatives of the Society to serve on the General Committee at the forthcoming Jubilee Meeting of the Manchester and Salford Sanitary Association.

The Council arranged for the Wilde Lecture to be delivered on Tuesday, February 25th, 1902, by Dr. Henry Wilde, F.R.S.

The following letter has been received by the Hon. Secretaries:—

14th April, 1902.

Dear Sirs,

I beg to inform you that at the Council Meeting of the Microscopical and Natural History Section of this Society, held this evening, it was resolved to discontinue the Section from this date, and to recommend such of its members as are members of the Society to make their communications on natural history and microscopical subjects, &c., to the ordinary meetings of the Society. The Treasurer of the Section, Mr. J. R. Ragdale, was at the same time authorised to pay over to the Society the balance standing at its credit with the St. Ann's Street Branch of the Williams Deacons Banking Co., Ltd., which will amount to £11 or £12, and to hand over all the account books, counterfoils of subscriptions received, and a list of subscriptions still owing to the Section, the proceeds of which are hereby transferred to the Society. These amount, roughly speaking, to about £4. The Section was also possessed of 3 binocular microscopes and their accessories, 4 cabinets of microscopic

slides, sundry collections of dredgings, etc., an album of members' photographs, besides a large tin box containing various papers, books, etc., the whole of which pass into the care of the Society now that the Section is disbanded. It is with much regret that the Council of the Section have, for some time, past seen no alternative to the proposals which have been to-night adopted. The Section was instituted in December, 1858, and was therefore within measurable distance of its Jubilee. It has done much useful work during that period, and the examination of its minute books will show that hardly a meeting was held that did not produce something that was worth hearing or seeing.

I am, yours faithfully,

J. COSMO MELVILL,

Hon. Sec.

Cato M. Guldberg was born in Christiania, August 11th, 1836, and entered the University of Christiania in 1854. He devoted himself to the study of science and mathematics, and in 1859 passed the State examination for Teachers in those subjects. He also won a Travelling Scholarship to be held for a year abroad. In 1860 he was appointed teacher in the Royal Norwegian Board School, and, in 1862, teacher at the Royal Military High School.

At this time he commenced the work on Chemical Affinity in conjunction with Waage—work which was destined in a few years to become classical. In 1867 he was appointed "Universitäts-stipendiat" (giving one lecture a week), and, in 1869 was elected to the Chair of Applied Mathematics at Christiania.

Guldberg and Waage's great work "Etudes sur les affinités chimiques" appeared in 1867. The older theory of chemical affinity due to Bergman, who supposed that each body had a specific "attraction" for every other, had been modified by Berthollet who introduced the idea that chemical action depends not only on 'affinity' but also on the quantity of the

bodies reacting. Thus if A is in presence of B and C, for both of which it has affinity, it divides itself between B and C to form bodies AB and AC in quantities that depend upon the affinities and also on the quantities of the bodies concerned. But Berthollet supposed that when one of the products was precipitated or was gaseous it ceased to exercise affinity. Guldberg and Waage saw that the final division of a substance between two others depended upon a number of complex forces, and that the simplest way to determine the resultant force was to study the conditions when the chemical forces were in equilibrium. They showed that solids and gases might take an active part in the change proceeding.

It had already been shown, especially by the researches of Wilhelmy, of Berthelot and St. Gilles, and of Harcourt and Esson, that Berthollet's Law of Mass action held good in particular cases; they had shown that the rate of chemical change in liquids and substances in solution varied with the quantities of the reacting substances present at any moment. But Guldberg and Waage pointed out how very general is the *reversibility* of chemical reactions, and the final state is usually due to an equilibrium between *reciprocal* processes. The determination of the conditions of equilibrium in any reversible reaction affords the "affinity-coefficient," by which the whole course of the reaction may be deduced mathematically.

This work of Guldberg and Waage has had a most widely reaching effect on the study of chemical dynamics

Besides his great work on Chemical Affinity, Guldberg published important papers on molecular volumes, on the relation between the coefficients of elasticity and of expansion and the latent heat of fusion of metals, on the thermodynamics of solution and dissociation.

Guldberg, whose death occurred on January 14th, 1902, was elected an Honorary Member of this Society in 1894.

Like so many of his countrymen, he was a good English scholar, and was well acquainted with the work of English men of science. He was ever ready to discuss points in physical

chemistry, and to give to others the benefits of his deep learning and critical insight. In Guldberg the world has lost a great man of science, and many of us a sincere friend.

H. B. D.

In the remarkable development of zoological science which characterised the last three decades of the nineteenth century, the name of HENRI DE LACAZE-DUTHIERS stands as that of one of the most prominent pioneers. Possessed of remarkable powers of continuous detailed investigation combined with an enthusiasm and devotion to science which made him a leader of men, his influence upon the work of French zoologists and of others who came in contact with him was profound and far-reaching. There is, perhaps, no better testimony of the wonderful vitality of the French nation than the quantity of valuable work in such a science as zoology that has been accomplished by Frenchmen since the lamentable war of 1870, and of the many distinguished men who have taken part in producing this great result no one has played a more important part than de Lacaze-Duthiers. Of the numerous scientific memoirs and papers which we owe to his skill and industry, some are so well known to every student of zoology as to merit the distinction that is usually conveyed by the term "classical." The "Histoire Naturelle du Corail," which was published in 1863 and contained the results of his investigations upon the precious coral of commerce (*Corallium rubrum*) that he carried out on the coast of Algeria, is one of the best monographs upon a single species of invertebrate animals that has ever been written. Although there are some points in it that would have to be corrected, and some views that would be modified if the work were undertaken again with the help of modern methods and modern ideas, it is really very remarkable how much the young Frenchman saw and how accurate were his observations considering the imperfect resources he had at his disposal.

Among the other monographs that he published, the most important was that on the anatomy and development of *Den-*

talium, but those who are specially interested in the Mollusca are familiar with his pioneer work on the anatomy of such forms as *Pleurobranchia*, *Haliotis*, *Aspergillum*, *Testacella*, *Aplysia*, and many others. Concerning other groups of animals, such as the Tunicates, Worms, etc., de Lacaze-Duthiers also produced some excellent work which has taken an important place in zoological literature. But the labour of investigation, and the task of writing out the results of his investigations, and drawing those excellent figures,— so characteristic of his work — that illustrate his memoirs, do not form perhaps the most important part of the work of his life. As the founder of a famous journal, the "Archives de zoologie expérimentale," and as the founder of the Marine Zoological Stations at Roscoff and at Banyuls-sur-Mer, he sowed the seed and tended the seedling of a great tree of knowledge which will grow and spread its branches for a time longer than we can reckon.

The journal is one in which we find the very best work of the French zoologists. It is now indispensable to his country, and indeed, to all zoologists. Such a journal stimulates good work, just as it depreciates work that is careless or superficial. The Zoological Laboratory at Roscoff attracts, and will continue to attract, zoologists from England and elsewhere who wish to work at marine studies during the summer months, whilst the laboratory at Banyuls offers similar attractions for those who are fortunate enough to have the time to spare for similar work in the winter. Laboratories such as these, offering hospitality and assistance to Frenchmen, as well as to foreigners of various nationalities, stimulate that wholesome rivalry between nations which leads to mutual understanding and respect.

De Lacaze-Duthiers died on July 21, 1901, in his 81st year. His death removes from our midst a powerful man with a great influence for good. But his great work is not dead. In some respects it may be said to have only just begun, and the time of our real appreciation of his life is not yet. He was elected an honorary member of this Society in April, 1895.

S. J. H.

François Marie Raoult was born on May 10th, 1830, at Fournes, in the Département du Nord. He had no personal means, and after teaching privately became "aspirant-répétiteur," or supernumerary usher, at the Lycée of Rheims in 1853, the year in which he published his first paper on electric endosmosis in the *Comptes Rendus.* He occupied various teaching posts at the *Collège* or Municipal Secondary School of Saint Dié (1855), and the Lycées of Rheims (1856-9), Bar-le-Duc (1860) and Sens (1862), taking meanwhile the degree of *licencié-ès-sciences physiques* and the diploma of *agregé*, which allowed him to occupy a post of permanent master in a *lycée* or State Secondary School. At Sens he carried out a series of investigations on the electro-motive force of cells of the Daniell type, which he embodied in a thesis for the degree of *docteur-ès-sciences*, presented to and accepted by the Faculty of Sciences of Paris in 1864. The work was neglected at the time, and has only comparatively recently received a theoretical interpretation through the researches of Helmholtz on the thermodynamics of cells. This was followed by further memoirs on electro-chemistry, which soon won for their author a place in University teaching. He was appointed in 1867 as "chargé du cours de chimie" at the Faculté des Sciences of Grenoble, and became titular professor in 1870. He held this chair of chemistry until his death, on April 1st, 1901. The regulations enforcing retirement at the age of 70 had been suspended for him. During the years 1873-1892 he held the chair of chemistry and toxicology at the École de Médecine et de Pharmacie in addition to his other chair.

Down to the year 1870 his memoirs dealt chiefly with electro-chemistry. They include, however, a memoir on the absorption of hydrogen by nickel, which has found a recent application in the work of Sabatier and Senderens on the hydrogenation of unsaturated hydro-carbons in the presence of this metal. During the years 1870 to 1882 he published a number of memoirs on the absorption of gases by solutions and solids, and especially of carbonic acid by the alkaline earths. In 1873

he confirmed the work of Roscoe and Dittmar on the absorption of ammonia by water, which had been criticised by Carius, and he proceeded to shew that concentrated solutions of ammonium nitrate and sodium nitrate absorb the same volume of ammonia as pure water, and that the same amount of heat is evolved when a given weight of ammonia is dissolved in various solutions.

It was as a fit reward to long, patient, and ingenious work on many subjects that Raoult had the good fortune to discover one of the most important laws in physical chemistry, and to open up a new and most fruitful domain. Blagden was the first to draw attention, in 1788, to the lowering of freezing points produced by the solution of a solid in water, and to show that, in general, for dilute solutions the lowering was proportional to the concentration of the solution. Rüdorff, in 1861 and 1862, re-discovered Blagden's law. In 1871 L. C. de Coppet extended Rüdorff's work, and shewed that the 'molecular lowering' was the same for groups of allied salts in water. Raoult, who began his work on the subject in 1878, studied the depression of the freezing point not only in water but in other solvents, and shewed that the aqueous solutions of inorganic salts, to which his predecessors had devoted their attention, behaved exceptionally. With most solvents he found that the depression of the freezing point was the same for solutions containing the same number of molecules of dissolved substance per litre, or, to use an accepted phrase, that for a given solvent 'the molecular depression' was the same for all dissolved substances (1882). It became possible by the new method to determine the molecular weight of an immense number of organic compounds of which the vapour density could not be obtained. His discovery of the general law for dilute solutions was thus of great value and importance not only to physical chemistry, but to chemistry generally. But the discovery that the behaviour of water as a solvent was exceptional and not normal proved perhaps of equal importance. Arrhenius pointed out in 1887 that the abnormally large depressions of the freezing point occurred only in the case

of electrolytes, and suggested that in aqueous solutions these were split up into ions, each of which behaved as a single molecule in depressing the freezing point. The number of ions could be calculated from the conductibility of the solution ; and Arrhenius's theory has received experimental confirmation in many cases, although there are still many results not in harmony with it. It constitutes a first approximation to the truth.

Raoult in his first paper on freezing points recalled the fact that not only the depression of the freezing point but also the fractional depression of the vapour tension [$(f-f')/f$ where f is the vapour tension of the pure solvent, f' that of the solution] was proportional to the concentration in dilute solutions. This was discovered by Wüllner, and Guldberg (*see* p. lvi, above) had indeed, in 1870, shewn that the one phenomenon could be deduced from the other by thermodynamical reasoning. In 1886 van't Hoff shewed how the absolute value of both depression of freezing point and fractional lowering of the vapour tension could be deduced from the osmotic pressure of a solution, and in 1887 Raoult published an experimental confirmation of van't Hoff's formula for certain substances. It was the first of a long series of researches on 'tonometry' of solutions, as elaborate and careful as those on their 'cryoscopy.' It is by his work on these two subjects that he will be remembered. He wrote nearly 60 memoirs dealing with them, in addition to two excellent summaries, '*Tonométrie*,' published in May, 1900, and '*Cryoscopie*,' published posthumously, in 1901, in the 'Scientia' series. The most general expression for the tonometric constant of a solution in terms of the other quantities involved was given in a joint paper by M. Raoult, and M. Recoura, Dean of the Faculty of Sciences of Dijon, Raoult's son-in-law.

'Ce grand savant, était aussi le meilleur des hommes.' Raoult was a man of remarkable simplicity of character, free from any trace of affectation or conceit, and admirably courteous and kind in manner. He was devoted to chemistry and to the provincial university which he served for 34 years, and which he

refused to leave when asked to go to Paris, just as Bunsen refused to quit Heidelberg for Berlin.

Raoult received many honours: the *prix Lacaze* in 1889, the Davy medal of the Royal Society in 1892, the great '*prix biennal*' of 20,000 francs of the French Institute in 1895. He was elected a Correspondent of the French Academy of Sciences in 1890, and Foreign Member of the Chemical Society in 1898. He had been an honorary member of our Society since 1892.

The above notice is based partly on personal knowledge, but mainly on information kindly supplied by M. Recoura; on speeches made at M. Raoult's funeral by M. Boirac, rector of the Académie de Grenoble, and M. Kilian, professor at the University of Grenoble; on a preface to M. Raoult's book *La Cryoscopie*, written by M. R. Lespieau; and on the abstract of Prof. van't Hoff's Memorial Lecture on Raoult, given to the Chemical Society, March 26th, 1902, (*Chem. Soc. Proc.*, 1902, p. 81).

P. J. H.

Henry Augustus Rowland, Ph.D., LL.D., For. Mem. R.S., Professor of Physics in the Johns Hopkins University, Baltimore, U.S., Honorary Member of this Society since 1894, died on the 16th April, 1901.

Born at Henesdale, Pa., on the 27th November, 1848, he was trained as an engineer at the Troy Polytechnic Institute, spent a short time as civil engineer on the railway, and in 1871 became teacher of Physics at Wooster College. Next year he returned to Troy, first as instructor in Physics, then as professor of Physics, and in 1875 became professor of Physics at Baltimore. He had already published several papers on magnetic permeability, and during his visit to Europe previous to commencing his duties at Baltimore he carried out in Helmholtz's laboratory at Berlin, his important experiments on the magnetic effect of electrical convection. His work at the Johns Hopkins University was confined almost exclusively to research and post graduate instruction. He turned his attention first to a determination of the Mechanical Equivalent of Heat, the result of which he published in 1880, and in 1882 described his wonderful concave grating, by means of which he carried out a long series of

researches on the wave lengths of lines of the solar spectrum, culminating in his Photographic map of the Normal Solar Spectrum.

In recent years his attention was directed chiefly to alternating electric currents and their application in telegraphy, and he served on several International Electrical Congresses.

He took a keen interest in scientific research, and was a severe critic, both of his own and of others work.

(See obituary notice in *Amer. Journ. Sci.*, xi., 1901, p. 459.)

C.H.L.

Peter Guthrie Tait, M.A., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh, Honorary Member of this Society since 1868, died on the 4th July, 1901.

He was born at Dalkeith, on the 28th April, 1831, and after being educated at the Academy and the University, Edinburgh, entered Peterhouse, Cambridge, in 1848. He was senior wrangler and 1st Smith's Prizeman, and was elected Fellow and Mathematical Lecturer of his College in 1852. In 1854 he became Professor of Mathematics at Queen's College, Belfast, and in 1860 succeeded Forbes as Professor of Natural Philosophy in the University of Edinburgh, a position he resigned, owing to ill health, in February, 1901.

During his career he published more than a hundred scientific memoirs, which have been collected in two quarto volumes, and ten treatises on various departments of natural philosophy. Of the treatises, that on Dynamics, the beginnings of a general work on Natural Philosophy, written in conjunction with Lord Kelvin, is invaluable to student and teacher alike, while those on Heat, Light, and Properties of Matter have proved their utility as text books by passing through several editions.

Tait's scientific work covered a wide ground. His work on the "Foundations of the Kinetic Theory of Gases" is of fundamental importance in the subject, and shows the depth of his mathematical knowledge, while his work on Thermo-electricity, equally fundamental, and his contributions to the "Physics and

Chemistry" of the "Challenger" expedition, show his skill as an experimenter.

He was awarded a Royal Medal by the Royal Society of London in 1886, and the Keith Medal of the Royal Society of Edinburgh in 1869 and again in 1874. He was for more than twenty years General Secretary to the latter Society, whose affairs he guided with his characteristic "clearness of vision and purity of purpose."

(See obituary notice by Lord Kelvin in *Proc. Roy. Soc Edin., Vol. xxiii. (1901), p. 498.*) C. H. L.

JOHN HAMPDEN BECKETT, only son of James Marshal Beckett, died at his residence, Corbar Hall, Buxton, on October 3rd, 1901, in his 46th year. He was elected a Fellow of the Chemical Society in 1882, and became an ordinary member of this Society on January 9th, 1894.

By the death of Dr. HENRY BROWNE, the Society not only lost one of its oldest members, but a man who was a remarkable personality in relation to the period in which he lived. As a physician and teacher, he may be said to have belonged to the period preceding the development of the doctrine of evolution and the germ theory of disease, though he outlived both Darwin and Pasteur—the first born a few years before him and the second a few years later. As a thinker in an age of criticism and scepticism, he was distinguished for the depth of his religious feeling, and he retained into the twentieth century an undiminished faith in the divine authority of the Scriptures. Nevertheless, alike as a medical practitioner and as a theologian, he was essentially scientific and critical. In the exercise of his profession, his religious convictions had a large influence; though, at the time of his death, nearly a quarter of a century had passed since his retirement from professional labour, and, owing to his exceptional length of life, very many of those who best knew him had preceded him to the grave, yet the number of persons in humble life who attended his funeral testified to

an affectionate remembrance of his reputation for gentleness, patience, and skill, for a peculiarly sympathetic and refined simplicity of character, and for unwearying ministration to the wants of the sick poor of the district in which he lived. In the days of his professional activity his name was a household word amongst the latter class; the curious visitor to his grave will find a noteworthy illustration of this fact in the tombstone record of the interment there, nearly forty years ago, of Annie, "wife of Dr. Browne," no more precise indication of the good Doctor's individuality being considered necessary at that time.

Henry Browne was born on February 13, 1818, and was the second son of George Buckston Browne, of Myrtle Grove, Halifax, in the County of Yorkshire, a gentleman of independent fortune, who had also, however, studied medicine, and was fully qualified for practice. The father of Henry was the only child of a George Buckston Browne, of whom it is recorded that he was a mcst successful medical practitioner in Manchester. In Mrs. Raffald's "Directory of Manchester," published in 1772, a Dr. Brown is mentioned as a physician at the Manchester Infirmary; the name, as printed, lacks the final letter, but that is not sufficient reason for dismissing the speculation that Henry's grandfather may have occupied the post from which the grandson retired about a century later. At the age of fifteen Henry Browne became a pupil of Dr. Tate, then head-master of Richmond Grammar School, in Yorkshire, and subsequently a Residentiary Canon of St. Paul's Cathedral, London. While a pupil at the Richmond School, the youth, during a summer holiday, came under the influence of the religious teaching of the Wesleyan denomination, and it is said that this fact caused him to choose the University of Glasgow for his further studies, instead of proceeding to Trinity College, Cambridge, as originally proposed by his father. At Glasgow, he graduated B.A. in 1839, and on April 29, 1840, was "capped on the black-stone" as M.A. In his diary is the following entry:—"The memories of Professor Thompson, and especially of Professor Nicholl, are very dear, as well as the funeral of Sir D. K.

Sandford memorable." A fellow student of Browne's in the humanity class was William Thomson, now Lord Kelvin. On September 28, 1840, Browne entered as a medical student at King's College, London, and in due course, after serving for a year as the resident physician's assistant, was admitted M.R.C.S. Eng., in 1844. He took the M.D. of London University in 1848. During those days he enjoyed the friendship of George Johnson, afterwards Sir George Johnson, a celebrated physician. Meanwhile he had left the Wesleyan denomination on doctrinal grounds, and had become a member of the Congregational or Independent body of Nonconformists, to which he remained attached for the rest of his life, eventually becoming a member of the congregation worshipping in Rusholme Road Chapel, Manchester, of which the late Dr. Alexander Thomson was for so many years the pastor. It was in 1845, prior to taking his doctor's degree, that Browne settled in Manchester, where he was appointed Lecturer on Forensic Medicine in the Pine Street "Royal Medical and Surgical School." He immediately associated himself with the general intellectual life of the city, purchasing a share in the Portico, Mosley Street, and being elected a member of the Manchester Literary and Philosophical Society on January 27, 1846. Though he never served as an officer or member of the Council of the Society, or contributed to its *Proceedings* or *Memoirs*, he continued a loyal member and subscriber to its funds until his death—a period of 56 years. In 1846 he was elected Physician to the Chorlton-on-Medlock Dispensary. On May 16, 1849, he married Annie, the second daughter of George Hadfield, a well-known Manchester solicitor, who for many years represented Sheffield in Parliament; and by her he had six children, one of whom, Henry, died in infancy, the rest, a son and four daughters, surviving him. Of these survivors one is Mr. George Buckston Browne, a London surgeon (the fourth generation in the medical profession), and another became Mrs. James Watts. In 1849 Dr. Browne was appointed Lecturer in Medicine at the Manchester School, and in August, 1853, he was appointed Physician to the Manchester

Royal Infirmary, a post to the duties of which he very diligently attended until 1878, when, being 60 years of age, he resigned it in accordance with the rules of the institution, and was appointed Consulting Physician. Throughout his life in Manchester he was a devoted supporter of the City Mission, and from its first establishment was a warm friend of the Hospital for Incurables at Mauldeth Hall—the former residence of the first Bishop of Manchester, Dr. James Prince Lee. Dr. Browne became a widower in 1864, and in 1868 he married Sophia Watson, of London, who died in 1879. He himself died peacefully of heart failure on December 28, 1901, within a few weeks of the completion of his 84th year; and on December 31 he was interred in the Hadfield Vault in Rusholme Road Cemetery, Manchester, where also lie the remains of his first and second wife, his infant son, and those of Lydia, wife of George Hadfield, who died in 1866, aged 80 years, and of George Hadfield, who died in 1879, aged 91 years.

Dr. Browne contributed little to medical literature. In 1857 he published a lecture "On the Laws of Health and their Correspondence with Revealed Truth," in 1865 he contributed to the *British Medical Journal* an article on "Oral, Gastric, and Duodenal Dyspepsia," and in 1867 there appeared in the same journal a paper from his pen on "Positive Nosology." His medical studies were devoted rather to the actual practice of his profession, in which he was very actively engaged, and to personal teaching, not only as a lecturer, but in conversation with those who came under his professional treatment, or who were admitted to his acquaintance, than to controversial exposition. That he enjoyed teaching younger men was certain, and was naively indicated on one occasion in his later years by the remark that he would like to have been a Professor at the Victoria University. Many of those who came under his care, as pupils, or otherwise, have risen to positions of influence or distinction and gratefully recognise the value of his teaching, enhanced, as it was, by the pleasant frankness and charm of his manner. One of the most eminent of these is Sir William

Broadbent who, long ago a student in the Pine Street School of Medicine, was in 1857 an unsuccessful candidate for the appointment of Junior House Surgeon in the Manchester Royal Infirmary, and subsequently proceeded to London, where he became Physician to St. Mary's Hospital, Physician Extraordinary to her late Majesty Queen Victoria and to his present Majesty the King, and was rewarded with a baronetcy in 1893. Dr. Browne's influence on medical and scientific progress was indeed rather personal than through the agency of his pen; he was an observer and a practical utiliser of the fruits of experience, rather than a theorist. But his influence stimulated thought in others, in regard to which he was tolerant and appreciative. As a medical man he was in many respects in advance of the general ideas of his time. When Pasteur's experiments on the attenuating influence of oxygen were first attracting attention he wrote, characteristically: "That oxygen is the ameliator of virulence is, as you remark, very gratifying, and especially so to you and me; for without knowing anything of bacteria we have always made much of fresh air." However strongly his philanthropic instincts tempted him in favour of particular movements, he still demanded a strict recognition of facts. Thus at one time he seemed disposed to co-operate actively with the temperance reformers, but he subsequently complained of a want of candour and fair play on their part, because they had objected to an admission to the effect that experience had taught him that excessive tea-drinking often did more harm than the excessive consumption of alcohol. While, with reference to the vivisection controversy, he admitted that some of the experiments on dogs and monkeys "really seemed too bad," he ungrudgingly recognised that vast benefit had resulted from experiments on animals. He recorded with pleasure a meeting with Pasteur, and also with Mr. (subsequently Sir) John Simon,—formerly his "grinder" at King's College—the latter of whom "discoursed at length on the benefit of cultivating germs," at the International Medical Congress in 1881.

Notwithstanding the apparent austerity of his life, Dr.

Browne was not deficient in the sense of humour; with a youthful and congenial patient—and he had a smile in the eyes as well as round the mouth, which induced confidence in the youthful—he could even perpetrate a pun at the bedside. His literary recreation as a busy medical man, and in the closing years of his life, was the study of Biblical literature. He once told the present writer that he would have been glad to give his life to the examination of the Greek and Hebrew texts; and after his retirement from the practice of his profession he appears to have taken up this study with increased zest. In 1881 he published a substantial volume, the nature of which is sufficiently indicated by the title, "John's Apocalypse: Literally Translated and Spiritually Interpreted;" and the year of his death saw the appearance of what has been described as the work of his life, a large octavo volume of upwards of 500 pages, entitled the "Triglot Dictionary of Scriptural Representative Words in Hebrew, Greek, and English." There will doubtless be many persons, philologists as well as commentators, who will consider Dr. Browne's opinions on these matters extreme; there may even be only a few theologians who will be able to carry their faith as far as he carried his. But a noteworthy fact is that even in these, perhaps too mystical, inquiries, the characteristic scientific qualities of his mind were displayed as in his medical practice. He insists on the value of facts and experiences in preference to literary elaboration. In such interpretation, he maintains, "there is no place for human imagination or fanciful poetical figure." However uncouth a literal translation may be, it will at least be most free from any admixture of "man's mistakes." He claims that in the "Triglot Dictionary" every English word is now "exclusively associated with one Greek word and with one Hebrew word, which Greek and Hebrew words not only fairly represent each other, but often throw fresh light upon each other"; whereas, even in the Revised Version of the Scriptures, as many as fifty or sixty English equivalents have been given for one word or phrase in the original text. What is

more, he claims that, when the one meaning has been selected, it "makes sense" in every case in which the original appears. Moreover, many doctrinal difficulties are found to disappear. "The Scriptures," he adds, "do not teach science, but they anticipate it." This is not the place in which to attempt any criticism of Dr. Browne's opinions on these matters, or any estimate of the extent to which his conclusions may appear justified; nor would the task be congenial to the present writer. But it will not be improper to point out the continuity of his mental attitude. An approximately parallel case seems to be that of Michael Faraday, who is incidentally mentioned by Henry Browne in the introduction to the "Triglot Dictionary." In his famous lecture on "Mental Education" before the Prince Consort in 1854, Faraday said:—"High as man is placed above the creatures around him, there is a higher and far more exalted position in view; and the ways are infinite in which he occupies his thoughts about the fears, or hopes, or expectations of a future life. I believe that the truth of that future cannot be brought to his knowledge by any exertion of his mental powers, however exalted they may be; that it is made known to him by other teaching than his own, and is received through simple belief of the testimony given." Faraday knew that he would be charged with inconsistency for this declaration; and he anticipated the charge by saying that he was "content to bear the reproach." But, accepting his premises, the inconsistency was only superficial. In questioning the Book of Nature, Faraday insisted on direct experiment, first-hand reading, so to speak, and distrusted all speculation. Accepting the Scriptures as revelation, he also insisted on undiluted literalness in that case. Describing Faraday's sermons as an elder of the communion to which he belonged, Dr. Bence Jones says:—"His object seemed to be to make the most use of the words of Scripture, and to make as little of his own words as he could." A rationalist and strict observer of facts in medicine, Dr. Henry Browne, as a theologian, demanded the literal rendering of the earliest texts, and to those who were sceptical as to the results his reply was—"above all, let us all be experimentalists." It was as an aid to experiment in the direction indicated that in the last year of his long and beneficent life he gave his "Triglot Dictionary" to the world.

F. J. F.

MANCHESTER LITERARY AND

Dr. *J. J. Ashworth, Treasurer, in Account with the*

	£ s. d.	£ s. d.
To Cash in hand, April 1st, 1901		34 5 1
To Members' Subscriptions:—		
Half Subscriptions, 1900-1901, 1 at £1. 1s. 0d.	1 1 0	
" " 1901-02, 11 " "	11 11 0	
Subscriptions:— 1895-96, 1 " £2. 2s. 0d.	2 2 0	
" 1896-97, 1 " "	2 2 0	
" 1899-1900, 1 " "	2 2 0	
" 1900-01, 7 " "	14 14 0	
" 1901-02, 119 " "	249 18 0	
" 1902-03, 2 " "	4 4 0	
		287 14 0
To Member's Extra Subscription		25 0 0
To Honorarium for Wilde Lecture returned		15 15 0
To Contributions from Sections:—		
Microscopical and Natural History Section, 1900-1901 and 1901-1902		10 10 0
To Transfers from the Wilde Endowment Fund	81 10 0	
To Special Transfer do. do. 1901-1902	40 0 0	
		121 10 0
To Sale of Publications		13 3 5
To Dividends:—		
Natural History Fund	57 16 1	
Joule Memorial Fund	7 5 10	
		65 1 11
To Income Tax Refunded:—		
Natural History Fund	3 3 10	
Joule Memorial Fund	0 8 4	
		3 12 2
		£576 11 7

WILDE ENDOWMENT

	£ s. d.
To Balance from 1900-1901	85 1 8
To Dividends on £7,500 Gas Light and Coke Company's Ordinary Stock	303 3 8
To Remission of Income Tax, 1901	16 19 8
To Bank Interest	1 6 5
	£406 11 5

NATURAL HISTORY

	£ s. d.
To Dividends on £1,225 Great Western Railway Company's Stock	57 16 1
To Remission of Income Tax, 1901	3 3 10
To Balance against this Fund, April 1st, 1902	54 3 8
	£115 3 7

JOULE MEMORIAL

	£ s. d.
To Balance, April 1st, 1901	33 17 2
To Dividends on £258 Loan to Manchester Corporation	7 5 10
To Remission of Income Tax, 1901	0 8 4
	£41 11 4

DALTON TOMB

	£ s. d.
To Balance, April 1st, 1901	31 3 8
To Bank Interest	0 15 6
	£31 19 2

PHILOSOPHICAL SOCIETY.

Society, from 1st April, 1901, to 31st March, 1902. **Cr.**

	£ s. d.	£ s. d.
By Charges on Property :—		
Chief Rent (Income Tax deducted) ..	12 3 10	
Income Tax on Chief Rent ..	0 15 0	
Insurance against Fire ..	13 17 6	
Repairs to Buildings, &c. ..	3 7 1	
		30 3 5
By House Expenditure :—		
Coals, Gas, Electric Light, Water, Wood, &c. ..	20 19 1	
Tea, Coffee, &c., at Meetings ..	19 18 9¼	
Cleaning, Sweeping Chimneys, &c. ..	3 9 3½	
		44 7 2
By Administrative Charges :—		
Housekeeper ..	57 4 0	
Postages, and Carriage of Parcels and of "Memoirs" ..	43 6 6	
Stationery, Cheques, Receipts, and Engrossing ..	8 5 6	
Printing Circulars, Reports, &c. ..	15 13 3	
Printing Articles of Association ..	6 0 0	
Illuminated Addresses to Glasgow University and to Owens College ..	6 15 0	
Legal Charges ..	2 2 0	
Bank Interest ..	0 9 3	
Miscellaneous Expenses ..	1 11 0	
		141 6 6
By Publishing :—		
Honorarium for Editing the "Memoirs" (Session 1900-1901) ..	50 0 0	
Printing "Memoirs and Proceedings" ..	158 19 2	
Illustrations for "Memoirs" (except Natural History Plates) ..	12 16 6	
Binding "Memoirs" ..	2 0 0	
		223 15 8
By Library :—		
Books and Periodicals (except on Natural History ..	38 3 2	
Catalogue Cards ..	1 10 0	
		39 13 2
By Natural History Fund :— (Items shown in the Balance Sheet of this Fund) ..		57 0 10
By Joule Memorial Fund :— (No Expenditure this Session) ..		0 0 0
By Balance at Bank ..	30 4 10	
,, ,, in Treasurer's hands ..	10 0 0	
		40 4 10
		£576 11 7

FUND, 1901—1902.

	£ s. d.	£ s. d.
By Assistant Secretary's Salary, April, 1901, to March, 1902 ..		144 0 0
By Maintenance of Society's Library :— Binding and Repairing Books ..		32 12 11
By Honorarium to Lecturer ..		15 15 0
By Transfers to Society's Funds ..	81 10 0	
By Special Transfer, 1901-1902 ..	40 0 0	
		121 10 0
By Cheque Book ..		0 2 6
By Balance at Bank, April 1st, 1902 ..		92 11 0
		£406 11 5

FUND, 1901—1902.

	£ s. d.
By Balance against, April 1st, 1901 ..	58 2 9
By Natural History Books and Periodicals ..	40 3 2
By Plates for Papers on Natural History in "Memoirs" ..	16 17 8
	£115 3 7

FUND, 1901—1902.

	£ s. d.
(No expenditure this Session).	
By Balance, April 1st, 1902 ..	41 11 4
	£41 11 4

FUND, 1901-1902.

	£ s. d.
(No Expenditure this Session.)	
By Balance at Bank, April 1st, 1902 ..	31 19 2
	£31 19 2

NOTE.—The Treasurer's Accounts of the Session 1901-1902, of which the preceding pages are summaries, have been endorsed as follows:

April 18th, 1902. Audited and found correct.

We have also seen, at this date, the certificates of the following Stocks held in the name of the Society:—£1,225 Great Western Railway Company 5% Consolidated Preference Stock, Nos. 12,293, 12,294, and 12,323; £258 Twenty years' loan to the Manchester Corporation, redeemable 25th March, 1914 (No. 1564); £7,500 Gas Light and Coke Company Ordinary Stock (No. 6,389); and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying the land on which the Society's premises stand, and the Declaration of Trust.

(Signed) THOMAS THORP.
GEORGE WILSON.

THE COUNCIL
AND MEMBERS
OF THE
MANCHESTER
LITERARY AND PHILOSOPHICAL SOCIETY.

(Corrected to June 14th, 1902.)

President.
CHARLES BAILEY, M.Sc., F.L.S.

Vice-Presidents.
J. E. KING, M.A.
C. E. STROMEYER, M.Inst.C.E.
Sir WILLIAM H. BAILEY.
H. B. DIXON, M.A., F.R.S.

Secretaries.
FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.
CHARLES H. LEES, D.Sc.

Treasurer.
CHARLES BAILEY, M.Sc., F.L.S.

Librarian.
W. E. HOYLE, M.A., M.Sc., F.R.S.E.

Of the Council.
HORACE LAMB, M.A., LL.D., F.R.S.
J. COSMO MELVILL, M.A., F.L.S.
FRANCIS NICHOLSON, F.Z.S.
R. L. TAYLOR, F.C.S.
F. E. WEISS, B.Sc., F.L.S.
THOMAS THORP, F.R.A.S.

ORDINARY MEMBERS.

Date of Election.

1901, Dec. 10. Adamson, Harold. *Oaklands, Godley, near Manchester.*

1902, Mar. 18. Allen, J. Fenwick. 147, *Withington Road, Whalley Range, Manchester.*

1902, Jan. 21. Allott, Charles S., M.Inst.C.E. 519, *Stretford Road, Old Trafford, Manchester.*

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beaconsfield, Derby Road, Withington, Manchester.*

1896, Jan. 31. Armstrong, Frank. *The Rowans, Harboro' Grove, Harboro' Ro d, Ashton-on-Mer ey, Cheshire.*

1895, Jan. 8. Armstrong, George B. *Clarendon, Sale, Cheshire.*

1902, April 29. Arnold, Francis Sorell, M.B., Ch.B. (Oxon.). 468, *Moss Lane East, Manchester.*

1887, Nov. 16. Ashworth, J. J. 47, *Faulkner Street, Manchester.*

1865, Nov. 14. Bailey, Charles, M.Sc., F.L.S. *Atherstone House, North Drive, St. Annes-on-the-Sea, Lancs.*

1888, Feb. 7. Bailey, Alderman Sir William H. *Sale Hall, Sale, Cheshire.*

1895, Jan. 8. Barnes, Charles L., M.A. 10, *Nelson Street, Chorlton-on-Medlock, Manchester.*

1896, April 14. Behrens, George B. *The Acorns*, 4, *Oak Drive, Fallowfield, Manchester.*

1895, Mar. 5. Behrens, Gustav. *Holly Royde, Withington, Manchester.*

1898, Nov. 29. Behrens, Walter L. 22, *Oxford Street, Manchester.*

1901, Dec. 10. Benger, F. Baden, F.C.S., F.I.C. *The Grange, Knutsford, Cheshire.*

1868, Dec. 15. Bickham, Spencer H., F.L.S. *Underdown, Ledbury.*

1896, April 14. Bindloss, James B. *Elm Bank, Eccles, Lancs.*

1901, Nov. 12. Bles, A. J. S. *Palm House, Higher Broughton, Manchester.*

1896, April 28. Bolton, Herbert, F.R.S.E. *The Museum, Bristol.*

1861, Jan. 22. Bottomley, James, D.Sc., B.A., F.C.S. 220, *Lower Broughton Road, Manchester.*

1896, Oct. 6. Bowman. F.H., D.Sc., F.R.S.E., *Spinningfield, Deansgate, Manchester.*

1896, Feb. 18. Bowman, George, M.D. 594, *Stretford Road, Old Trafford, Manchester.*

1875, Nov. 16. Boyd, John. *Barton House*, 11, *Didsbury Park, Didsbury, Manchester.*

Date of Election.

1889, Oct. 15. Bradley, Nathaniel, F.C.S. *Sunnyside, Whalley Range, Manchester.*

1894, Mar. 6. Broadbent, G. H., M.R.C.S. 8, *Ardwick Green, Manchester.*

1896, Nov. 17. Broderick, Lonsdale, F.C.A. *Somerby, Wilmslow, Cheshire.*

1861, April 2. Brogden, Henry, F.G.S., M.I.Mech.E. *Hale Lodge, Altrincham, Cheshire.*

1889, April 16. Brooks, Samuel Herbert. *Slade House, Levenshulme, Manchester.*

1860, Jan. 24. Brothers, Alfred. 117, *Summerfield Crescent, Edgbaston, Birmingham.*

1886, April 6. Brown, Alfred, M.A., M.D. *Sandycroft, Higher Broughton, Manchester.*

1889, Jan. 8. Brownell, T. W., F.R.A.S. 64, *Upper Brook Street, Manchester.*

1889, Oct. 15. Budenberg, C. F., M.Sc, M.I.Mech.E. *Bowdon Lane, Marple, Cheshire.*

1872, Nov. 12. Burghardt, Charles Anthony, Ph.D. 35, *Fountain Street, Manchester.*

1894, Nov. 13. Burton, William, F.C.S. *The Hollies, Clifton Junction, near Manchester.*

1899, Feb. 7. Chapman, D.L., B.A, Demonstrator and Assistant Lecturer in Chemistry. *Owens College, Manchester.*

1902, May 13. Chapman, Sydney J., M.A., Professor of Political Economy. *Owens College, Manchester.*

1901, Nov. 26. Chevalier, Reginald C., M.A., Mathematical Master at the Manchester Grammar School. 43, *Lansdowne Road, West Didsbury, Manchester.*

1901, Nov. 12. Coignou, Caroline, Science Mistress at the Manchester High School for Girls. 60, *Cecil Street, Greenheys, Manchester.*

1895, April 30. Collett, Edward Pyemont. 8, *St. John Street, Manchester.*

1884, Nov. 4. Corbett, Joseph. *Town Hall, Salford.*

1895, April 30. Cornish, James Edward. *Stone House, Alderley Edge, Cheshire.*

1859, Jan. 25. Coward, Edward, Assoc.Inst.C.E., M.I.Mech.E. *Heatherlea, Bowdon, Cheshire.*

1895, Nov. 12. Crossley, W. J., M.I.Mech.E. *Openshaw, Manchester.*

1876, April 18. Cunliffe, Robert Ellis. *Croft, Ambleside.*

1901, Nov. 26. Darbishire, Francis V., B.A., Ph.D., Assistant Lecturer and Demonstrator in Chemistry at the Owens College. *Hulme Hall, Plymouth Grove, Manchester.*

Date of Election.

1853, April 19. Darbishire, Robert Dukinfield, F.S.A. 1, *St. James' Square, Manchester.*

1895, April 9. Dawkins, W. Boyd, M.A., D.Sc., F.R.S., Professor of Geology. *Owens College, Manchester.*

1894, Mar. 6 Delépine, A. Sheridan, M.B., B.Sc., Professor of Pathology. *Owens College, Manchester.*

1902, April 29. Dendy, Mary. 13, *Clarence Road, Withington, Manchester.*

1887, Feb. 8. Dixon, Harold Bailey, M.A., F.R.S., Professor of Chemistry. *Owens College, Manchester.*

1898, Oct. 18. Donovan, E. W., M.I.Mech.E. *Hilton House, Prestwich. Lancs.*

1899, April 11. Earle, Hardman A. 40, *Oughton Road, Birkdale, Lancs.*

1902, May 13. Ellison, Robert William. 40, *Lincroft Street, Moss Side, Manchester.*

1883, Oct. 2. Faraday, F. J., F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1900, April 24. Faraday, Lucy Winifred, M.A. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1897, Oct. 19. Faraday, W. Barnard, LL.B. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1895, April 30. Flux, A. W., M.A., Professor of Political Economy. *McGill University, Montreal, Canada.*

1897, Nov. 30. Freston, H. W. 6, *St. Paul's Road, Kersal, Manchester.*

1898, Nov. 29. Gamble, F. W., D.Sc., Demonstrator and Assistant Lecturer in Zoology. *Owens College, Manchester.*

1900, Feb. 6. Goldthorpe, William. *Brook House, Burnage Lane, Levenshulme, Manchester.*

1896, Nov. 17. Gordon, Rev. Alexander, M.A. *Memorial Hall, Albert Square, Manchester.*

1900, Oct. 16. Grindley, J. H., M.Sc. *Technical College, Huddersfield.*

1897, Jan. 26. Grossmann, J., Ph.D. *Harpurhey Chemical Works, Harpurhey, Manchester.*

1890, Feb. 18. Harker, Thomas. *Brook House, Fallowfield, Manchester.*

1895, Nov. 12. Hartog, Philippe Joseph, B.Sc., F.C.S., Demonstrator and Assistant Lecturer in Chemistry. *Owens College, Manchester.*

1902, April 29. Herbert, Arthur M., B.A. *Park Avenue, Timperley, Cheshire.*

Date of Election.

1902, Jan. 7. Hewitt, David B., M.D. *Oakleigh, Northwich, Cheshire.*

1889, Jan. 8. Heywood, Charles J., *Chaseley, Pendleton, Manchester.*

1895, Mar. 5. Hickson, Sydney J., M.A., D.Sc., F.R.S., Professor of Zoology. *Owens College, Manchester.*

1901, Dec. 10. Hiles, Isa L., M.Sc., Science Mistress at the Manchester High School for Girls. *Stanton Avenue, Didsbury, Manchester.*

1884, Jan. 8. Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street, Manchester.*

1898, Nov. 29. Hopkinson, Alfred, K.C., M.A., LL.D., Principal of the Owens College. *Fairfield, Victoria Park, Manchester.*

1896, Nov. 3. Hopkinson, Edward, D.Sc., M.Inst.C.E. *Oakleigh, Timperley, Cheshire.*

1889, Oct. 15. Hoyle, William Evans, M A., F.R.S.E., Director of the Manchester Museum. *Owens College, Manchester.*

1900, Oct. 16. Hutton, R. S., M.Sc., Demonstrator and Assistant Lecturer in Electro-Chemistry. *Owens College, Manchester.*

1899, Oct. 17. Huxley, George, M.I.Mech.E. 20, *Mount Street, Manchester.*

1902, April 15. Hyde, Henry. 26. *South Grove, Brooklands, Cheshire.*

1899, Oct. 17. Ingleby, Joseph, M.I.Mech.E. *Ingleside, Marple Bridge, near Stockport.*

1901, Nov. 26. Jackson, Frederick. 14, *Cross Street, Manchester.*

1870, Nov. 1. Johnson, William H., B.Sc. 26, *Lever Street, Manchester.*

1896, Oct. 20. Jones, A. Emrys, M.D. 10, *St. John Street, Manchester.*

1878, Nov. 26. Jones, Francis, M.Sc., F.R.S.E., F.C.S. *Manchester Grammar School.*

1886, Jan. 12. Kay, Thomas. *Moorfield, Stockport, Cheshire.*

1891, Dec. 1. King, John Edward, M.A., High Master, *Manchester Grammar School.*

1895, Nov. 12. Kirkman, W. W. *The Grange, Timperley, Cheshire.*

1902, Feb. 4. Kolp, N. *Woodthorpe, Victoria Park, Manchester.*

1901, Oct. 29. Laidlaw, Frank F., B.A., Demonstrator and Assistant Lecturer in Zoology at the Owens College. 8, *Parsonage Road, Withington, Manchester.*

1893, Nov. 14. Lamb, Horace, M.A., LL.D., F.R.S., Professor of Mathematics. 6, *Wilbraham Road, Fallowfield, Manchester.*

1902, Jan. 7. Lange, Ernest F. *Fairholme*, 3, *Willow Bank, Fallowfield, Manchester.*

Date of Election.

1899, Feb. 7. Lawrence, W. T., B.A., Ph.D., Demonstrator and Assistant Lecturer in Organic Chemistry. *Owens College, Manchester.*

1895, Nov. 12. Lees, Charles Herbert, D.Sc., Lecturer in Physics at the Owens College. *Chevy Chase, Lorne Grove, Fallowfield, Manchester.*

1895, Mar. 5. Levinstein, Ivan. *Hawkesmoor, Wilbraham Road, Fallowfield, Manchester.*

1902, Jan. 7. Longridge, Michael, M.A., M.Inst.C.E. *Linkvretten, Ashley Road, Bowdon, Cheshire.*

1857, Jan. 27. Longridge, Robert Bewick, M.I.Mech.E. *Yew Tree House, Tabley, Knutsford, Cheshire.*

1898, Nov. 29. McConnel, J. W., M.A. *Wellbank, Prestwich, Lancs.*

1866, Nov. 13. McDougall, Arthur, B.Sc. *Fallowfield House, Fallowfield, Manchester.*

1902, Mar. 4. Mandleberg, G. C. *Carlton House, Broom Lane, Higher Broughton, Manchester.*

1875, Jan. 26. Mann, J. Dixon, M.D., F.R.C.P. (Lond.), Professor of Medical Jurisprudence at Owens College. 16, *St. John Street, Manchester.*

1896, Oct. 20. Massey, Leonard F. *Openshaw, Manchester.*

1901, Dec. 10. Massey, Herbert. *Ivy Lea, Burnage, Didsbury, Manchester.*

1864, Nov. 1. Mather, William, M.P., M.Inst.C.E., M.I.Mech.E. *Iron Works, Salford.*

1873, Mar. 18. Melvill, James Cosmo, M.A., F.L.S. *Brook House, Prestwich, Lancs.*

1896, Nov. 3. Milligan, William, M.D. *Westbourne, Wilmslow Road, Rusholme, Manchester.*

1881, Oct. 18. Mond, Ludwig, Ph.D., F.R.S., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1894, Feb. 6. Mond, Robert Ludwig, M.A., F.R.S.E., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1899, Mar. 7. Morris, Edgar F., M.A., F.C.S. *Grey House, Barrington Road, Altrincham, Cheshire.*

1902, Feb. 18. Moss, William E., B.A. *C/o Messrs. Davies, Benachi & Co.*, 7, *Rumford Street, Liverpool.*

1873, Mar. 4. Nicholson, Francis, F.Z.S. 84, *Major Street, Manchester.*

1900, April 3. Nicolson, John T., D.Sc. *Nant-y-Glyn, Marple, Cheshire.*

1889, April 16. Norbury, George. *Hillside, Prestwich Park, Prestwich, Lancs.*

Date of Election.

1884, Apri 15. Okell, Samuel. F.R.A.S. *Overley, Langham Road, Bowdon, Cheshire.*

1901, Nov. 26. Paine, Standen. *Dewsdale, Bowdon, Cheshire.*

1895, Nov. 12. Pennington, James Dixon, B.A., M.Sc. 254, *Oxford Road, Manchester.*

1892, Nov. 15. Perkin, W. H., jun., Ph.D., F.R.S., Professor of Organic Chemistry. *Owens College, Manchester.*

1901, Oct. 29. Petavel, J. E. *Owens College, Manchester.*

1885, Nov. 17. Phillips, Henry Harcourt, F.C.S. 9, *Crawford Avenue, Bolton, Lancs.*

1901, Nov. 12 Pratt, Edith M., M.Sc. *Peak House, Dukinfield, Cheshire.*

1900, Feb. 20. Ragdale, J. R. *The Beeches, Whitefield, near Manchester.*

1901, Dec. 10. Ramsden, Herbert, M.D. (Lond.), M.B., Ch.B. (Vict.). *Sunnyside, Dobcross, near Oldham, Lancs.*

1888, Feb. 21. Rée, Alfred, Ph.D., F.C.S, 15, *Mauldeth Road, Withington, Manchester.*

1901, Oct. 15. Reynolds, J. H., M.Sc., Principal, *Municipal School of Technology, Sackville Street, Manchester.*

1869, Nov. 16. Reynolds, Osborne, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering, Owens College. 19, *Ladybarn Road, Fallowfield, Manchester.*

1880, Mar. 23. Roberts, D. Lloyd, M.D., F.R.S.E., F.R.C.P. (Lond.). *Ravenswood, Broughton Park, Manchester.*

1864, Dec. 27. Robinson, John, M.Inst.C.E., M.I.Mech.E. *Westwood Hall, Leek, Staffs.*

1897, Oct. 19. Rothwell, William Thomas. *Heath Brewery, Newton Heath, near Manchester.*

1893, Mar. 21. Schill, C. H. 117, *Portland Street, Manchester.*

1896, Nov. 17. Schmitz, Hermann Emil, B.A., B.Sc. *Manchester Grammar School.*

1842, Jan. 25. Schunck, Edward, D.Sc., Ph.D., F.R.S., F.C.S. *Kersal, Manchester.*

1873, Nov. 18. Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics. *Kent House, Victoria Park, Manchester.*

1898, Jan. 25. Schwabe, Louis. *Hart Hill, Eccles Old Road, Pendleton, Manchester.*

1902, Jan. 21. Shann, T. T. *Meadow Bank, Heaton Norris, Stockport.*

1895, Nov. 12. Shearer, Arthur. 36, *Demesne Road, Alexandra Park, Manchester.*

1890, Nov. 4. Sidebotham, Edward John, M.A., M.B., M.R.C.S. *Erlesdene, Bowdon, Cheshire.*

Date of Election.

1901, Oct. 29. Sinclair, W. J., M.D., Professor of Obstetrics and Gynæcology. *Owens College, Manchester.*

1895, Nov. 12. Southern, Frank, B.Sc. 6, *Park Avenue, Timperley, Cheshire.*

1896, Feb. 18. Spence, David. *Pine Ridge, Buxton.*

1901, Dec. 10. Spence, Howard. *Audley, Broad Road, Sale, Cheshire.*

1896, April 14. Stanton, Thomas E., D.Sc. *National Physical Laboratory, Bushy House, Teddington, Middlesex.*

1894, Jan 9. Stevens, Marshall, F.S.S. 18, *Exchange Street, Manchester.*

1894, Nov. 13. Stirrup, Mark, F.G.S. *High Thorn, Stamford Road, Bowdon, Cheshire.*

1897, Nov. 30. Stromeyer, C. E., M.Inst.C.E. *Steam Users' Association,* 9, *Mount Street, Albert Square, Manchester.*

1895, April 9. Tatton, Reginald A., M.Inst.C.E., Engineer to the Mersey and Irwell Joint Committee. 44, *Mosley Street, Manchester.*

1893, Nov. 14. Taylor, R. L., F.C.S., F.I.C. *Central School, Whitworth Street, Manchester.*

1873, April 15. Thomson, William, F.R.S.E., F.C.S., F.I.C. *Royal Institution, Manchester.*

1896, Jan. 21. Thorburn, William, M.D., B.Sc. 2, *St. Peter's Square, Manchester.*

1896, Jan. 21. Thorp, Thomas, F.R.A.S. *Moss Bank, Whitefield, near Manchester.*

1899, Oct. 31. Thorpe, Jocelyn F., Ph.D., Demonstrator in Organic Chemistry. *Owens College, Manchester.*

1899, Oct. 17. Todd, W. H. *Greenfield, Flixton, near Manchester.*

1873, Nov. 18. Waters, Arthur William, F.L.S., F.G.S. *Sunny Lea, Davos Dorf, Switzerland.*

1892, Nov. 15. Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany, Owens College. 4, *Clifton Avenue, Fallowfield, Manchester.*

1895, April 9. Whitehead, James. *Lindfield, Fulshaw Park, Wilmslow, Cheshire.*

1901, Oct. 1. Wild, Robert B., M.D., M.Sc., M.R.C.P., Professor of Materia Medica and Therapeutics, Owens College. *Broome House, Fallowfield, Manchester.*

1859, Jan. 25. Wilde, Henry, D.Sc., F.R.S. *The Hurst, Alderley Edge, Cheshire.*

1859, April 19. Wilkinson, Thomas Read. *Vale Bank, Knutsford, Cheshire.*

Date of Election.	
1888, April 17.	Williams, Sir E. Leader, M.Inst.C.E., M.I.Mech.E. *Spring Gardens, Manchester.*
1896, Dec. 1.	Wilson, George, D.Sc., Demonstrator in Engineering. *Owens College, Manchester.*
1901, Nov. 26.	Wilson, William, M.A., Principal, *Royal Technical Institute, Salford.*
1860, April 17.	Woolley, George Stephen. *Victoria Bridge, Salford.*
1863, Nov. 17.	Worthington, Samuel Barton, M.Inst.C.E., M.I.Mech.E. *Mill Bank, Bowdon,* and 37, *Princess Street, Manchester.*
1865, Feb. 21.	Worthington, Thomas, F.R.I.B.A. 46, *Brown Street, Manchester.*
1895, Jan. 8.	Worthington, Wm. Barton, B.Sc., M.Inst.C.E. 2, *Wilton Polygon, Cheetham Hill, Manchester.*
1897, Oct. 19.	Wyatt, Charles H., M.A. *Chelford, Cheshire.*

N.B.—Of the above list the following have compounded for their subscriptions, and are therefore life members.

Bailey, Charles, M.Sc., F.L.S.
Bradley, Nathaniel, F.C.S.
Brogden, Henry, F.G.S.
Johnson, William H., B.Sc.
Worthington, Wm. Barton, B.Sc.

HONORARY MEMBERS.

Date of Election.	
1892, April 26.	Abney, Sir W. de W., K.C.B., D.Sc., F.R.S. *Rathmore Lodge, Bolton Gardens South, South Kensington, London, S.W.*
1892, April 26.	Amagat, E. H., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Honorary Professor, Faculté des Sciences, Lyon. 34, *Rue St. Lambert, Paris.*
1894, April 17.	Appell, Paul, Membre de l'Institut, Professor of Theoretical Mechanics. *Faculté des Sciences, Paris.*
1892, April 26.	Ascherson, Paul F. Aug., Professor of Botany. *Universität, Berlin.*
1889, April 30.	Avebury, John Lubbock, Lord, D.C.L., LL.D., F.R.S. *High Elms, Down, Kent.*
1892, April 26.	Baeyer, Adolf von, For. Mem. R.S., Professor of Chemistry. 1, *Arcisstrasse, Munich.*
1886, Feb. 9.	Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S. 2, *Queen Square Place, Westminster, London, S.W.*
1886, Feb. 9.	Baker, John Gilbert, F.R.S., F.L.S. 3, *Cumberland Road, Kew.*
1895, April 30.	Beilstein, F., Ph.D., Professor of Chemistry. *8th Line, N. 17, St. Petersburg, W.O.*
1886, Feb. 9.	Berthelot, Marcelin P. E., For. Mem. R.S., Membre de l'Institut Professor of Chemistry, Secrétaire perpétuel de l'Académie des Sciences. *Paris.*
1892, April 26.	Boltzmann, Ludwig, For. Mem. R.S., Professor of Physics. *K. K. Universität, Vienna.*
1886, Feb. 9.	Buchan, Alexander, M.A., LL.D., F.R.S., F.R.S.E. 42, *Heriot Row, Edinburgh.*
1888, April 17.	Cannizzaro, Stanislao, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Chemistry. *Reale Università, Rome.*
1889, April 30.	Carruthers, William, F.R.S., F.L.S. 14, *Vermont Road, Norwood, London, S.E.*
1866, Oct. 30.	Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy. 3, *Bardwell Road, Banbury Road, Oxford.*
1892, April 26.	Curtius, Theodor, Professor of Chemistry. *Universität, Kiel.*

Date of Election.

1892, April 26. Darboux, Gaston, Membre de l'Institut, Professor of Geometry, Faculté des Sciences, Secrétaire perpétuel de l'Académie des Sciences. 36, *Rue Gay Lussac, Paris.*

1894, April 17. Debus, H., Ph.D., F.R.S. 4, *Schlangenweg, Cassel, Hessen, Germany.*

1888, April 17. Dewalque, Gustave, Professor of Geology. *Université, Liége.*

1900, April 24. Dewar, James, M.A., LL.D., D.Sc., F.R.S., Fullerian Professor of Chemistry. *Royal Institution, Albemarle Street, London, W.*

1892, April 26. Dohrn, Dr. Anton, For. Mem. R.S. *Zoologische Station, Naples.*

1892, April 26. Dyer, Sir W. T. Thistelton, K.C.M.G., C.I.E., M.A., F.R.S., Director of the Royal Botanic Gardens. *Kew.*

1892, April 26. Edison, Thomas Alva. *Orange, N.J., U.S.A.*

1895, April 30. Elster, Julius, Ph.D. 6, *Lessingstrasse, Wolfenbüttel.*

1900, April 24. Ewing, James Alfred, M.A., F.R.S., Professor of Mechanism and Applied Mechanics. *Langdale Lodge, Cambridge.*

1889, April 30. Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*

1900, April 24. Forsyth, Andrew Russell, M.A., Sc.D., F.R.S., Sadlerian Professor of Pure Mathematics. *Trinity College, Cambridge.*

1889. April 30. Foster, Sir Michael, K.C.B., M.P., M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*

1892, April 26. Fürbringer, Max, Professor of Anatomy. *Grossherz. Universität, Jena.*

1892, April 26. Gegenbaur, Carl, For. Mem R.S., Professor of Anatomy. 57, *Leopoldstrasse, Heidelberg.*

1900, April 24. Geikie, James, D.C.L., LL.D., F.R.S., Murchison Professor of Geology and Mineralogy. *Kilmor e, Colinton Road, Edinburgh.*

1895, April 30. Geitel, Hans. 6, *Lessingstrasse, Wolfenbüttel.*

1892, April 26. Gibbs, J. Willard, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematical Physics. *Yale University, New Haven, U.S.A.*

1894, April 17. Glaisher, J. W L., Sc.D., F.R.S., Lecturer in Mathematics. *Trinity College, Cambridge.*

1894, April 17. Gouy, A., Professor of Physics. *Faculté des Sciences, Lyons.*

Date of Election.

1900, April 24. Haeckel, Ernst, Ph.D., Professor of Zoology. *Zoologisches Institut, Jena.*

1894, April 17. Harcourt, A. G. Vernon, M.A., D.C.L., F.R.S., V.P.C.S., Lee's Reader in Chemistry, Christ Church. *Cowley Grange, Oxford.*

1894, April 17. Heaviside, Oliver, F.R.S. *Bradley View, Newton Abbot, Devon.*

1892, April 26. Hill, G. W. *West Nyack, N. Y., U.S.A.*

1888, April 17. Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*

1892, April 26. Hoff, J. van't, Ph.D., For. Mem. R.S., Professor of Chemistry. 2, *Uhlandstrasse, Charlottenburg, Berlin.*

1892, April 26. Hooker, Sir Joseph Dalton, G.C.S.I., C.B., D.C.L., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *The Camp, Sunningdale, Berks.*

1869. Jan. 12. Huggins, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 90, *Upper Tulse Hill, Brixton, London, S.W.*

1851, April 29. Kelvin, William Thomson, Lord, G.C.V.O., M.A., D.C.L., LL.D., F.R.S., F.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.). *Netherhall, Largs, Ayrshire.*

1892, April 26. Klein, Felix, Ph.D., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics. 3, *Wilhelm Weber Strasse, Göttingen.*

1894, April 17. Königsberger, Leo, Professor of Mathematics. *Universität, Heidelberg.*

1892, April 26. Ladenburg, A., Ph.D., Professor of Chemistry. 3, *Kaiser Wilhelm Strasse, Breslau.*

1887, April 19. Langley, S. P., For. Mem. R.S. *Smithsonian Institution, Washington, U.S.A.*

1902, May 13. Larmor, Joseph, M.A., D.Sc., LL.D., Sec. R.S., F.R.A.S. *St. John's College, Cambridge.*

1892, April 26. Liebermann, C., Professor of Chemistry. 29, *Matthäi-Kirch Strasse, Berlin.*

1887, April 19. Lockyer, Sir J. Norman, K.C.B., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Science School, South Kensington, London, S.W.*

1902, May 13. Lodge, Oliver Joseph, D.Sc., LL.D., F.R.S, Principal of the University of Birmingham. *The University, Birmingham.*

1900, April 24. Lorentz, Henrik Anton, Professor of Physics. *Hooigracht, 48, Leyden.*

Date of Election.

1892, April 26. Marshall, Alfred, M.A., Professor of Political Economy. *Balliol Croft, Madingley Road, Cambridge.*

1892, April 26. Mascart, E. E. N., For. Mem. R.S , Membre de l'Institut, Professor at the Collège de France. 176, *Rue de l'Université, Paris.*

1889, April 30. Mendeléeff, D., Ph.D., For. Mem. R.S. *Université, St. Petersburg.*

1901, April 23. Metchnikoff, Élie, D.Sc., For.Mem.R.S. *Institut Pasteur, Paris.*

1895, April 30. Mittag-Leffler, Gösta, D.C.L. (Oxon.) For. Mem. R.S., Professor of Mathematics. *Djursholm, Stockholm.*

1892, April 26. Moissan, H., Membre de l'Institut, Professor of the Faculté des Sciences à la Sarbonne. 7, *Rue Vauquelin, Paris.*

1894, April 17. Murray, Sir John, K.C.B., LL.D., D.Sc., F.R.S. *Challenger Lodge, Wardie, Edinburgh.*

1894, April 17. Neumayer, Professor G., For. Mem. R.S., Director of the Seewarte. *Hamburg.*

1887, April 19. Newcomb, Simon, For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Mathematics and Astronomy. 1620, *P Street, Washington, D.C., U.S.A.*

1902, May 13. Osborn, Henry Fairfield, Professor of Vertebrate Palæontology, Columbia College, New York, *U.S.A.*

1894, April 17. Ostwald, W., Professor of Chemistry. 2/3, *Linnéstrasse, Leipsic.*

1899, April 25. Palgrave, R. H. Inglis, F.R.S., F.S.S. *Belton, Great Yarmouth.*

1892, April 26. Perkin, W. H., LL.D., Ph.D., F.R.S., V.P.C.S. *The Chestnuts, Sudbury, Harrow.*

1894, April 17. Pfeffer, Wilhelm, For. Mem. R.S., Professor of Botany. *Botanisches Institut, Leipsic.*

1892, April 26. Poincaré, H., For. Mem. R.S., Membre de l'Institut, Professor of Astronomy. 63, *Rue Claude Bernard, Paris.*

1892, April 26. Quincke, G. H., For. Mem. R.S., Professor of Physics, *Universität, Heidelberg.*

1899, April 25. Ramsay, William, Ph.D., F.R.S., Professor of Chemistry. 12, *Arundel Gardens, Notting Hill, London, W.*

1849, Jan. 23. Rawson, Robert, F.R.A.S. *Havant, Hants.*

Date of Election.

1886, Feb. 9. Rayleigh, John William Strutt, Lord, M.A., D.C.L. (Oxon.), LL.D. (Univ. McGill), F.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Terling Place, Witham, Essex.*

1900, April 24. Ridgway, Robert, Curator of the Department of Birds, U.S. National Museum. *Brookland, District of Columbia, U.S.A.*

1897, April 27. Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., V.P.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 10, *Bramham Gardens, Earl's Court, London, S.W.*

1889. April 30. Routh, Edward John, D.Sc., F.R.S. *Newnham Cottage, Queen's Road, Cambridge.*

1889, April 30. Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Provost's House, Trinity College, Dublin.*

1894. April 17. Sanderson, Sir J. S. Burdon, Bart., M.A., M.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Regius Professor of Medicine. *University, Oxford.*

1902, May 13. Scott, Dukinfield Henry, M.A., Ph.D., F.R.S., F.L.S., Honorary Keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew. *Old Palace, Richmond, Surrey.*

1892. April 26. Sharpe, R. Bowdler, LL.D., F.L.S., F.Z.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

1892, April 26. Solms, H. Graf zu, Professor of Botany. *Universität, Strassburg.*

1869, Dec. 14. Sorby, Henry Clifton, LL.D., F.R.S., F.L.S., F.G.S. *Broomfield, Sheffield.*

1851, April 29. Stokes, Sir George Gabriel, Bart., M.A., LL.D., D.C.L., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Lucasian Professor of Mathematics. *Lensfield Cottage, Cambridge.*

1886, Feb. 9. Strasburger, Eduard, D.C.L., For. Mem. R.S., Professor of Botany. *Universitat, Bonn.*

1895, April 30. Suess, Eduard, Ph.D., For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Geology. 9, *Africanergasse, Vienna.*

1895, April 30. Thomson, Joseph John, M.A., Sc.D., F.R.S., Professor of Experimental Physics, 6, *Scrope Terrace, Cambridge.*

1894, April 17. Thorpe, T. E., C.B., Ph.D., D.Sc., LL.D., F.R.S., V.P.C.S. *Government Laboratory, Clements Inn Passage, Strand, London, W.C.*

1900, April 24. Tower, Beauchamp, M.Inst.C.E. *Warley Mount, Brentwood, Essex.*

Date of Election.

1894, April 17. Turner, Sir William, K.C.B., M.B., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy. 6, *Eton Terrace, Edinburgh.*

1886, Feb. 9. Tylor, Edward Burnett, D.C.L. (Oxon.), LL.D. (St. And. and McGill Colls.), F.R.S., Professor of Anthropology. *Museum House, Oxford.*

1894, April 17. Vines, Sidney Howard, M.A., D.Sc., F.R.S., Sherardian Professor of Botany. *Headington Hill, Oxford.*

1894, April 17. Warburg, Emil, Professor of Physics. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Ward, H. Marshall, D.Sc., F.R.S., Professor of Botany. *Botanical Laboratory, New Museums, Cambridge.*

1894, April 17. Weismann, August, Professor of Zoology. *Universitat, Freiburg i. Br.*

1889, April 30. Williamson, Alexander William, Ph D., LL D., F.R.S., V.P.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *High Pitfold, Shottermill, Haslemere, Surrey.*

1886, Feb. 9. Young, Charles Augustus, Professor of Astronomy. *Princeton College, N.J., U.S.A.*

1888, April 17. Zirkel, Ferdinand, For. Mem. R.S., Professor of Mineralogy. *Thalstrasse*, 33, *Leipsic.*

1895, April 20. Zittel, Carl Alfred von, Professor of Palæontology and Geology. *Universtät, Munich.*

CORRESPONDING MEMBERS.

1850, April 30. Harley, Rev. Robert, Hon. M.A. (Oxon.), F.R.S., F.R.A.S., Hon. Memb. R.S. Queensland. *Rosslyn, Westbourne Road, Forest Hill, London, S.E.*, and *The Athenæum Club, London, S.W.*

1882, Nov. 14. Herford, Rev. Brooke, D.D. 91, *Fitzjohn's Avenue, Hampstead, London, N.W.*

1859, Jan. 25. Le Jolis, Auguste François, Ph.D., Archiviste-perpétue of the Soc. Nat. Sci. Cherbourg. *Cherbourg.*

Awards of the Wilde Medal under the conditions of the Wilde Endowment Fund.

1896. Sir GEORGE G. STOKES, Bart., F.R.S.
1897. Sir WILLIAM HUGGINS, K.C.B., F.R.S.
1898. Sir JOSEPH DALTON HOOKER, G.C.S.I., C.B., F.R.S.
1899. Sir EDWARD FRANKLAND, K.C.B., F.R.S.
1900. Rt. Hon. LORD RAYLEIGH, F.R.S.
1901. Dr. ÉLIE METCHNIKOFF, For. Mem. R.S.

Awards of the Dalton Medal.

1898. EDWARD SCHUNCK, Ph.D., F.R.S.
1900. Sir HENRY E. ROSCOE, F.R.S.

Awards of the Premium under the conditions of the Wilde Endowment Fund.

1897. PETER CAMERON.
1898. JOHN BUTTERWORTH, F.R.M.S.
1899. CHARLES H. LEES, D.Sc.
1900. Prof. A. W. FLUX, M.A.
1901. THOMAS THORP.

THE WILDE LECTURES.

1897. (July 2.) "On the Nature of the Röntgen Rays." By Sir G. G. STOKES, Bart., F.R.S. *(28 pp.)*

1898. (Mar. 29.) "On the Physical Basis of Psychical Events." By Sir MICHAEL FOSTER, K.C.B., F.R.S. *(46 pp.)*

1899. (Mar. 28.) "The newly discovered Elements; and their relation to the Kinetic Theory of Gases." By Prof. WILLIAM RAMSAY, F.R.S. *(19 pp.)*

1900. (Feb. 13.) "The Mechanical Principles of Flight." By the Rt. Hon. LORD RAYLEIGH, F.R.S. *(26 pp.)*

1901. (April 22.) "Sur la Flore du Corps Humain." By Dr. ÉLIE METCHNIKOFF, For. Mem. R.S. *(38 pp.)*

1902. (Feb. 25.) "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion." By Dr. HENRY WILDE, F.R.S. *(34 pp., 3 pl.)*